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AIR FORCE MASTER PLAN - SIMULATORS FOR AIRCREW TRAINING

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SIMULATORS FOR AIRCREW TRAINING

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AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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The application of simulators for aircrew training in the United States Air Force is addressed. Major operating commands provided current and projected requirements for aircrew training simulators for incorporation into formal training programs together with estimates of their impact on flight training. A simulator technology overview is provided and a technology research program is proposed to support future acquisitions. Estimates of program costs are made and the magnitude of potential direct operating costs and fuel savings are presented for each of the acquisition programs. Institutional and management problems are also addressed.

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This document represents the work of many people and organizations. Sincere appreciation is expressed to representatives of the Major Operating Commands for their cooperation and considerable effort to provide relevant data. Similarly, appreciation is expressed to the Air Force Logistics Command for assistance in addressing questions of commonality, maintenance and logistics support of simulators. The Air Force Human Resources Laboratory, the Simulator and Human Factors Division, Directorate of Crew and AGE Engineering (ASD/ENCT), and the Simulator System Program Office (ASD/SMS) provided the material covering the technology overview, technology programs and forecasts of acquisition programs. The support of individuals in the Deputy for Development Planning was invaluable in producing the Plan and special appreciation is expressed to Mrs. Mary Layman for the prodigious task of typing and preparing the manuscript for publication.

FOREWORD

Headquarters USAF/CSAF message 081500Z, dated October 1973, directed the development of an Air Force Master Plan for Simulators for Aircrew Training and designated the Air Force Systems Command as the lead command. The AFSC/Aeronautical Systems Division, Deputy for Development Planning was subsequently assigned as the Office of Primary Responsibility. The message directed that the Plan should address but not be limited to the following:

- "Identification of the most immediate and effective action for increased simulator use;
- "Identification of reduction of flying hours made possible by increased simulator use;
- "Increased research and development of simulation technology;
- "Development and procurement of additional simulators; and
- "Recommended budget to support decisions."

The Plan is intended to be useful in achieving the Secretary of Defense Management Objective #6 which states that each service should increase its use of flight simulators consistent with effectiveness of training, costs and operation. To achieve this objective requires:

a. Review of the current status of flight simulators;

b. Definition of programs for increased use of simulators in Undergraduate Pilot Training, Aircrew Operational Readiness Training and Operational Crew Training;

c. Development and acquisition of simulators; and

d. Increased utilization of simulators be considered carefully so as to have the least risk to operational capability.

In keeping with these objectives, a concerted effort was undertaken by the Air Force Major Commands to assess their present training programs and to identify their needs relative to increased use of simulators for aircrew training. Personnel from the Major Commands worked with representatives of the Air Force Human Resources Laboratory, Air Force Logistics Command, and elements of the Aeronautical Systems Division to translate these needs into programs and associated fiscal support requirements. The management structure for simulator research, development and acquisition was studied to determine areas where management improvements could be made. In addition, research and development programs for simulator technology and human learning experimentation were examined to ensure that viable programs were proposed to support future simulator hardware requirements and to enhance our understanding and application of training transfer phenomena.

In accordance with the Deputy Secretary of Defense Program Budget decision of 9 December 1974 and by direction of the Commander of the Air Force Systems Command, this document updates and replaces the initial Air Force Master Plan dated June 1974. Format changes include the placement of cost estimates in a separate Annex A and the Analysis of Program Data in Annex B. Annex C contains a summary of an investigation to address the question of commonality in which a common motion base is hypothesized for a number of future simulators. Cost benefits are quantified and the impact of implementing a commonality decision is discussed.

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INTRODUCTION

A. BACKGROUND

1. In January 1969 a "Special Report of the USAF Scientific Advisory Board, Human Resources Panel, Visit with the Airline Industry" discussed the procedures being utilized in training and upgrading airline pilots. The panel concluded that the Air Force would be rewarded by studying the airline's experience and recommended that the Air Force initiate studies to determine ways of improving present pilot training methodology as a result of the work done by civilian airlines. The conclusion and recommendation were considered valid even though the panel recognized both the differences in duties, requirements, and responsibilities of Air Force and airline pilots and that certain areas of training are not directly comparable.

2. In early 1969 a report was published based on a USAF Ad Hoc Review of Airline Pilot Training. The report highlighted the facts that:

a. "The basic goal of each airline training program is to qualify the graduate to pass a Federal Aviation Agency (FAA) rating check. Students are experienced pilots ranging from NEW HIRES with 1,000 flying hours to Airline Captains with many thousands of flying hours."

b. "By comparison, Air Force pilot training ranges from Undergraduate Pilot Training (UPT) to a variety of Combat Crew Training Schools (CCTS). In UPT the training task is one of teaching new skills in an environment strange to the trainee. In some CCTS the pilot must acquire the skill, knowledge and mental discipline to perform as an aircraft commander -- often for a combat environment." The Ad Hoc Review concluded that the Air Force can profit from adopting some of the methodology and techniques used by the airlines. It also recommended that:

"(1) The USAF should apply the latest developments in educational design to its flying training programs. This includes the systems approach, which combines the latest in learning and communication theories with multimedia devices to accelerate and individualize training."

"(2) R&D effort directed toward instructional systems application should be continued and expanded."

3. The Air Force Chief of Staff, General McConnell, in a letter dated 16 June 1969, transmitted the Ad Hoc Review to all major Air Force organizations. The Chief of Staff expressed his increasing concern "with the rising costs of pilot training" and stated that "the recommendations stated in this document deserve careful and decisive evaluation by all commanders and their staff managers who conduct or maintain pilot training programs."

4. The Air Force Chief of Staff, General Ryan, in a letter dated 2 February 1970 to the five major operating Commands, referred to General McConnell's letter and listed five "principles that I would like to see incorporated into our flying programs:

a. Ensure that each course is structured to contain precisely the training required;

b. Give only training appropriate to the individual;

c. Measure training on proficiency, not course length;

d. Make maximum use of least cost training before progressing to more costly training; and

e. When a skill is particularly difficult, seek ways to alter the task to make it easier."

5. In January 1974, the Air Force Energy R&D Steering Group was formed to review the future of the Air Force and to suggest R&D programs which would help alleviate future energy problems. A set of findings was published in November 1974, some of which were pertinent to the role simulators are expected to play in the Air Force future.

The report noted that the Air Force is the largest government user of petroleum-based energy. While this use represents only about 2 percent of our Nation's total petroleum consumption, about 90 percent of that is used in flying. The report further noted that for the foreseeable future, there is no way to avoid operating with petroleum-based fuels and that there is no practical way in the near term either to develop and produce new kinds of fuel suitable for aircraft operations or to convert existing aircraft propulsion systems to such new fuels. The report concluded that there is a "problem" period of 10 to 15 years during which we have to rely on existing fuels and propulsion systems. During this period, the only available techniques for coping with the problem are conservation and some modifications of existing systems to improve their efficiency.

The Steering Group's recommendations included a proposal to introduce a concept of "Energy Effectiveness" as a measure of merit in all studies and management decisions. It noted that, "Owing to the rising cost of energy and its impact on life cycle costs, the most cost effective alternative now may also be the most energy effective."

A pertinent recommendation was that the Air Force should establish goals for the reduction of flying hours through the use of simulators.

6. The following progress was made from early 1969 through mid 1975:

a. In response to ATC ROC 5-68, June 1968, the Aeronautical Systems Division of AFSC, along with Air Training Command and the Air Force Human Resources Laboratory, developed a data bank and analytical tools through two contracted studies on Future Undergraduate Pilot Training, 1975-1990. These data and tools were employed by an Air Force mission analysis team in applying the systems approach to Future UPT. The final report, January 1972, recommended that ATC implement various instructional techniques and establish a requirement for an instrument flight simulator with a visual system.

b. During this time period the Tactical Air Command initiated an Instructional Systems Development (ISD) program for the A-7D CCTS in December 1970. Instructional System Development as defined in AFM 50-2 and AFP 50-58 "is a deliberate and orderly process for planning and developing instructional programs which ensure that personnel are taught the knowledge, skills, and attitudes essential for successful job performance. The process depends on a description and analysis of the tasks necessary for performing the job, criteria, objectives and tests clearly stated before instruction begins, evaluation procedures to determine whether or not the objectives have been reached, and methods for revising the process based on empirical data." By August 1971, the aircrew task analysis had identified the required procedures and skills, and a training syllabus defined the least-cost, efficient mix of cockpit procedures trainers, flight simulators (no visual) and aircraft so that the A-7D CCTS training program would provide the specific training needed by the A-7D pilots to become operationally combat ready.

c. ISD for Transition Training (Phase I) and Mission Qualification Training (Phase II) is complete for F-4, RF-4, F-111, A-7D, F-15 and AC-130 aircraft. ISD is in process for Continuation Training (Phase III) for the above aircraft. ROCs have been submitted to add visual systems to the A-7D simulators and to modify the F-4E simulators with visual systems and g-seat/g-suit/buffet devices, and to acquire new F-4E Full Mission Simulators. ISD teams have been established for the A-10 and E-3A aircraft and will be complete in October 1975. ISD will also be applied to the F-4 Wild Weasel and EF-111A Tactical Jamming Simulators.

d. The Military Airlift Command initiated ISD efforts for the C-141 and C-5 Transition Training Units (TTU) in February 1972. These syllabi were completed in July 1974. ISD for the UH-1, CH-3 and HH-53 was initiated in 1973. The CH-3 ISD was completed in September 1974 and the HH-53 in Feburary 1975. The C-130 is in progress and will be completed in the second quarter of 1978. A modification for an additional limited visual capability for the C-5/C-141 simulators at Altus AFB was completed in April 1975.

e. The Strategic Air Command initiated ISD efforts for the B-52 and KC-135 in December 1973 through contracts with Hughes and Logicon, respectively, to develop the necessary aircrew task analyses. These efforts were completed in February 1975. B-1 ISD was initiated within the B-1 SPO. An exercise called "Giant Sample" was initiated at SAC to quantify B-52 and KC-135 skill maintenance needs to determine flying minimums for pilot skill maintenance. A DC-130 controller trainer is under contract and prototype boom operator and aerial refueling part task trainers will be under contract this year. The B-52 and KC-135 Instructional Systems are in the early stages of the acquisition process. The Ogden ALC has been directed to modify FB-111 simulators with limited visual systems.

f. The Aerospace Defense Command initiated an ISD effort for the F-106 in September 1973 through a contract with Logicon to develop the aircrew task analysis. This effort was completed in February 1974. Prototyping of 23 modifications to the MB-42 simulator was accomplished at Tyndall AFB. Kit deliveries will begin in November 1975 and extend to March 1976.

g. The Air Training Command ISD efforts on Undergraduate Navigator Training (UNT) were initiated in 1971, Electronic Warfare Officer (EWO) and Navigator/Bombardier Training (NBT), Pilot Instructor Training (PIT) and Instrument Pilot Instructor School (IPIS) in June of 1973. The T-45 Undergraduate Navigator Training Simulator was fully integrated into the course in October 1975; the Simulator for Electronic Warfare Training was introduced in January 1974 making the Electronic Warfare Officer Training course a no-fly course; and, the Undergraduate Pilot Training Instrument Flight Simulator is in procurement with first delivery scheduled for CY 77.

h. In the case of new weapon systems procurements, the ISD process is being initiated by the operational commands early in the weapon system's development cycle. The aircrew task analyses and syllabi are scheduled to be completed early enough so that an ISD developed CCT program will be available to train the aircrews for the initial production aircraft. The new weapon systems include the F-15, F-16, AWACS, A-10 and B-1.

i. Three significant advanced development first article programs were initiated to develop and evaluate a broad spectrum of wide angle visual systems. They are: F-4 Project #18, capable of simulating the visual air-to-ground weapon delivery task; the Simulator for Air-to-Air Combat (SAAC); and the Advanced Simulator for Undergraduate Pilot Training (ASUPT), capable of performing most of the UPT tasks. These simulators have been delivered and are now undergoing testing. These programs, along with other simulator development efforts, are discussed in more detail in Section II, Overview of Simulator Technology.

j. In May 1973 the AFSC, Aeronautical Systems Division, established a Simulator System Program Office to manage the development and acquisition of simulators.

7. Four recent simulator studies completed by the Assistant Chief of Staff, Studies and Analysis (July 1972), USAF Scientific Advisory Board (January 1973), Office of Management and Budget (July 1973), and General Accounting Office (August 1973) concluded that the Air Force has not fully exploited the potentialities of simulators for aircrew training to achieve reductions in actual flight time requirements. The reasons cited for lack of Air Force progress toward full utilization of simulators were generally not technological but rather were ascribed to management

constraints, budget limitations and negative attitudes on the part of aircrew members and commanders. On the other hand, the studies generally agreed there is a lack of quantitative data which can be used to compare simulator training with aircraft training. In addition to these study findings, the energy crisis, the escalating costs of aircraft procurement and operation, and the need to extend the life of operational aircraft, necessitate near-term major capital investments to accelerate improved simulator capabilities and subsequent expanded utilization. Upon this basis, and with a positive attitude to build upon the progress which has been made as noted previously, a review of the Major Command programs and the technology base was undertaken as the first step in the development of the initial Master Plan.

B. CONCEPT OF THE MASTER PLAN

Emphasis was placed on achieving the objectives expressed in the Foreword; namely, to identify and define programs which would result in greater simulator use and a concomitant reduction in aircraft flying hours required for equivalent training of aircrew members. It is clear that this view is limited and while it is believed to be a proper first objective in the development of a Master Plan, a larger scope is required if it is to be useful in continuing to provide guidance for decisions concerning simulation for aircrew training. To that end, it is important to recognize that planning is a continuing function and a plan is today's view of how to proceed. Since the Plan itself is temporal, it is important that the Master Plan provide the means for its own continuity and updating. This leads to the need to address the management structure and the interrelated objectives of organizations to provide a coherent environment for making decisions, implementing programs, and definitizing the plans treated in rather gross aspect in this document. It must also identify the means for ensuring a continuity of technology base development and the related process of training value assessment. The essentiality of establishing the framework for continuing communications between user, developer, evaluator, and budget authority should transcend our desires for immediate, precise and immutable solutions to long standing problems. Sections III and IV of this document discuss improved management for a class of training devices which has been generically referred to as "simulators." In fact, the devices discussed in this Plan are better described as a more general class of synthetic training devices ranging from procedures trainers to full mission simulators. As such, they represent media in the instructional process and can be productive or counter-productive dependent upon their design, and perhaps even more importantly, their use in the field. As will be noted in each of the sections discussing individual operating command perceived needs, a recurrent theme emerges: the universal acceptance of the Instructional System Development (ISD) approach to optimization of media use. It is not too much of an extrapolation to believe that a systematic approach to requirements development and the establishment of a convergent dialogue with the developers and budget approval agencies will meet with universal acceptance in future years. Indeed, if that dialogue is permitted to be dropped upon the publication of any given document, the Master Plan will have failed to yield any benefits. It may in fact be counter-productive in that initial dialogues are often misleading and continuous dialogue is needed to formulate superior options, identify better decision criteria and develop a more rigorous data base for promulgating and defending future programs.

It is believed therefore, that the Management area is at least as important as the programming data presented herein. It is urgent that management roles continue to be clarified and funding mechanisms be set up to provide stability and continuity for simulator exploratory, advanced and engineering development alongside programs to provide an improved understanding of the training value and transferability of skills learned on a simulator to operational skills in the aircraft.

C. APPROACH

Most of the peacetime flying in the Air Force today is devoted to training. The small mission support effort is the only significant exception. Undergraduate Pilot Training Transition Training, Continuation Training, and a limited proficiency flying program consume nearly all of the USAF flying hours. Some supplemental benefits are gained, such as cargo delivery in MAC training flights, but the principal objective is flight training. The addition of the combined flight activity of the Air Force Reserve and the Air National Guard would increase total Air Force flight activity by about 12%. Most of the activity in Instructional System Development has been concentrated in the five Major Commands; ATC, ADC, MAC, SAC and TAC. In addition, MAC, SAC and TAC provide much of the Combat Crew Training for pilots assigned to PACAF, USAFE, AF Reserves and the Air

National Guard. Initial emphasis was therefore placed on the five Major Commands and was further restricted to undergraduate training, transition training and continuation training.

Figure I-1 diagramatically represents the approach taken. The major activity centered on discerning Command status and perceived needs to accomplish the objectives of increased simulator use and reduction of flying hours. Each block is discussed briefly below. Parallel to this activity, an effort was initiated to review the management structure relative to simulator research, development, acquisition and operation with the objective of suggesting ways to streamline and improve the process.

Block $\boxed{1}$ <u>Training Needs</u> - The Operational Commands were requested to provide the following information using five tiers of consideration:

I. Status Quo - Describe the current training programs as to types, numbers and characteristics of current simulators (including part task trainers, cockpit procedures trainers, and instrument trainers).

- Identify the number of training hours spent by each aircraft crew member in each type of simulator and aircraft for UPT, Phase I and II (Transition) and Phase III (Continuation).

- Identify the direct operating and maintenance costs for each type simulator and aircraft.

II. More Efficient Use of Existing Equipment

- Identify number of flying hours that could be reduced through use of ISD principles, new instructional methodologies, etc.

III. Additional Quantities of Existing Equipment

- Identify training areas where flying hours could be reduced through procurement of additional quantities of exising equipment.

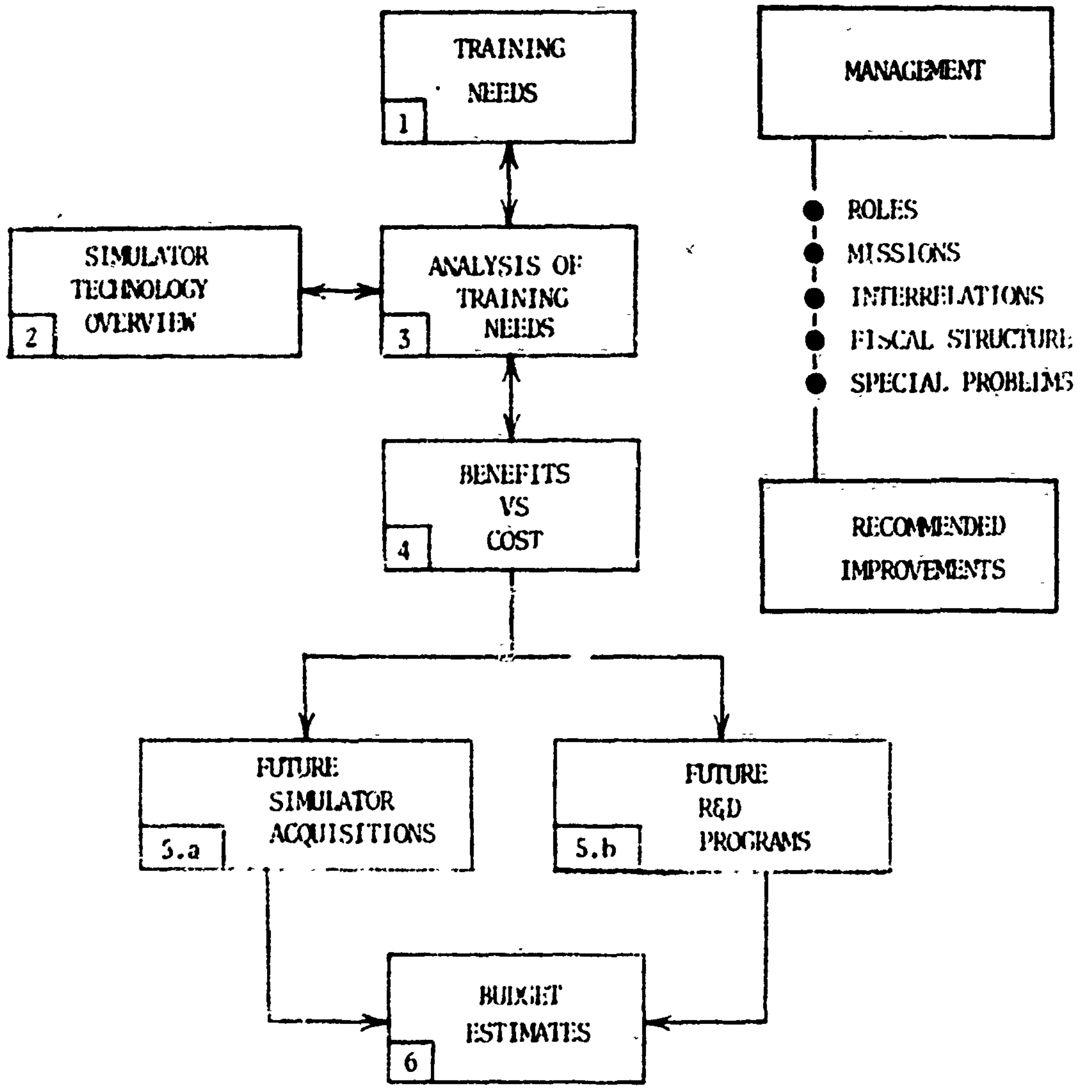


FIGURE I-1

APPROACH FOR SIMULATOR MASTER PLAN

IV. Modifications to Existing Equipment

- Identify training areas where flying hours could be reduced through updating the configuration or adding visual systems or improving the motion system of current simulators.

V. New Capabilities Needed

- Identify training areas where flying hours could be reduced through acquisition of simulators that either incorporate current technology or are dependent upon satisfactory completion of current exploratory and advanced development programs or future development programs.

Block [2] Simulator Technology Overview - The ASD/ENCT and AFHRL were requested to provide the following:

- Evolution of Flight Simulation in Training.
- Feasibility of Modifying Existing Simulators.
- Current Simulator Development Status.
- Research and Development Programs.

Block [3] Analysis of Training Needs

- The ASD, HRL and Operational Commands analyzed the ability of technology to satisfy the training capabilities identified by the Operational Commands. The simulator acquisition programs were described, time phased, and cost-estimated by ASD. In this process, each perceived training need was translated into a conceptual (engineering) entity. A categorization of the item was then made to place it in a common perspective. Table I-1 illustrates this categorization

TABLE I-1

INVESTMENT CATEGORIES VS TIERS OF CONSIDERATIONS

INVESTMENT CATEGORY	TIERS OF CONSIDERATION	
	I	Status Quo.
1	II	More efficient use of existing equipment (apply ISD team, more personnel, etc.).
2	III	New buys of existing equipment.
3	IV	Modifications to existing equipment:
		a. Update simulator to latest aircraft configuration.
		b. Modernize configuration; i.e., replace analog with digital computers.
		c. Add-on capability, example: Add visual.
	V	New capabilities needed;
4		a. Technology is state-of-the-art and similar hardware has been produced and training effectiveness has been determined.
5		b. Technology is state-of-the-art, but hardware has not been produced and training effectiveness has not been determined.
6		c. Advanced Development.
7		d. Exploratory Development - establish feasibility of techniques.
8		e. Research and/or study.

process. Using the category as a guide, the acquisition programs were developed around milestones representing needed action dates (viz., submission of a ROC, Program Management Directive, contract initiation date, and delivery schedule). These dates were predicated upon prompt action by the various agencies involved; however, the span of time between actions is based upon historical experience.

Block 4 Benefits versus Cost

- The ASD compared the simulator R&D/Acquisition costs with quantitative and qualitative benefits. Where possible, the simulator programs that promise higher benefits (reduced flying hours and reduced fuel, etc.) were identified.

Blocks 5.a. and 5.b. Future Simulator Acquisitions and R&D Programs

- The ASD summarized acquisition programs based on program start dates. R&D programs were categorized as to their applicability to only one versus many of the operational aircraft.

Block 6 Budget Estimates

- The ASD summarized by FY the funding associated with each simulator R&D and acquisition program.

SECTION II

OVERVIEW OF SIMULATOR TECHNOLOGY

A. THE EVOLUTION OF FLIGHT SIMULATION IN TRAINING

The history of the development of the technology for flight simulation in training, as we know it today, originated in the "Link Trainer" of World War II and significant advances in the technology have occurred progressively in programs that can be categorized in steps of approximately ten years duration.

The original Link Trainer design was based upon the utilization of instrumentation systems that were largely mechanical in nature. In the late 1940s, techniques were developed to replace these mechanical systems with electrical and electronic designs.

At approximately the turn of the decade (1950s), the analog flight simulator was developed for training. This simulator employed special purpose, fixed wired computer systems that solved certain special purpose, and simplified equations for the forces and motion of the aircraft simulated under very limited conditions. These original analog techniques, which were used until the latter part of the 1950s, employed an a.c. carrier design that added to the special purpose nature of the simulation. The d.c. analog computer systems were introduced in this period and provided a more scientific and general purpose approach to simulator design. This design approach was used almost exclusively until the development of the digital computer. It was also during this period that several attempts were made to develop visual simulation devices. Some of these attempts resulted in laboratory test articles that were based entirely on optical principles. However, because of poor aerodynamic simulation and poor image quality, none of these were sufficiently realistic to be suitable for training. This period also saw the continuing development of sensor simulators which simulated the operation of airborne radar systems. These early simulations utilized a technique that employed ultrasonic waves which were transmitted through water to a 3-D model of the area represented. Although the approach was very crude, limited in operation, and difficult to modify, many trainers employing this design were used in aircrew training. This period saw the introduction of the photo-transparency approach for radar landmass simulation. The first systems encoded the data in shades of gray, using one transparency for radar reflectivity and another for elevation information. Later systems used a single transparent map and had both elevation and cultural information stored by using three colors (red and blue for elevation, green for culture). The technique utilized a flying spot scanner tube to scan the map and then process the resultant amount of light such that a realistic presentation of radar information was displayed on the operator's indicator. This photographic approach, with some recent improvements, is still the system installed in most of the present day Air Force simulators. During this period, simulation of electronic warfare equipment was introduced. These systems used analog techniques for the simulation of the emitters and countermeasures. Although quite cumbersome to operate and maintain, these systems provided an effective training capability for electronic warfare officers. Motion systems were also beginning to evolve through several stages utilizing a variety of mechanisms ranging from pneumatic actuators and gear driven mechanical systems to hydraulic systems which became predominant toward the end of the decade.

Early in the 1960s, the development of a real time, medium sized digital computer was completed and demonstrated to be suitable for training simulation. Since analog computers had been used in simulation for approximately 20 years, a considerable amount of inertia existed in the Air Force and in industry in converting to digital simulation. Some firms converted immediately to digital systems while others approached more cautiously by first developing hybrid and special purpose digital techniques. It was also during this period that the development of a model board and TV approach to visual simulation was initiated. However, during this period, "concurrency" was the theme in system acquisition (i.e., new technology developments were attempted concurrent with the development of a new system) and the visual simulation technique was a "concurrent" development. Like many other concurrent programs, this visual simulation effort resulted in a "disaster" and the resulting hardware was not usable. Later in the 1960 decade, three additional attempts were made at concurrent visual simulation development, however, none of these were successful either. From these first attempts to develop visual systems, the Services and industry learned many things which were later applied in the formulation of an exploratory development interim visual simulation program and in the development of a successful technique, which was originally applied by the commercial airlines. In the visual simulation area two significant advances were made. One program advanced the band pass of video systems from 4 MHz to 30 MHz, and the other program developed an optical probe with infinity depth of focus. Conceptual studies were conducted for the development of techniques for generating radar simulation using digital techniques; however, due to the limited resources, no hardware was developed.

In the 1970s, the band pass of video systems was increased and successful work was done in both narrow and wide field of view optical probes. These techniques demonstrated that wide angle, high resolution, infinite depth of focus visual image generation, based upon probe and TV, was now feasible, although, specific systems will usually require additional development in such areas as probe mechanization. The remaining problems to be solved for a wide angle visual technique are in the image processing and display areas. The first successful Air Force development of a visual simulation system in an operational organization has been completed on the C-5/C-141 system. This is considered an interim system, similar to the airlines, and contains the advanced "Duo-View" display system. Two significant large and complex advanced development programs in the simulation area were initiated early in the 1970s. One is the Advanced Simulator for Undergraduate Pilot Training (ASUPT) and is intended for research programs in the UPT area. The other is the Simulator for Air-to-Air Combat (SAAC) and is intended to demonstrate the utility of simulation for training and research in air-to-air combat. In addition to providing large and complex simulation systems for training and research, the ASUPT and SAAC provide a means for the development and demonstration of advanced simulation technology. The ASUPT has advanced technology in computer image generation (CIG), large CRT displays, "g" seat and advanced instructional capabilities. The SAAC will demonstrate advances in one-on-one aerial combat tactics, segmented virtual image displays and high resolution double raster image assembly techniques. A program has recently been completed for adding visual simulation to an advanced F-4E fighter simulator (F-4E #18). This is based upon the application of the wide angle probe and image intensifier combined with a high resolution color TV system. A radar simulation system for the F-111 simulator is being developed based upon the application of digital techniques that were previously studied.

With the advent of increased activity in electronic warfare and the limited airspace available for airborne training, digital techniques are being applied in the development of the Simulator for Electronic Warfare Training (SEWT). With the introduction of SEWT in January of 1974, the Electronic Warfare Officer Training Course at ATC became a no-fly program.

A program has been initiated to develop techniques for simulation of infrared and low light level television systems, based upon the application of digital image generation techniques. Mathematical and programming techniques are being developed to automate some of the functions of the simulator instructor. Results have indicated a considerable amount of success in techniques for objective performance measurement, automated task selection and variable task difficulty. These techniques open up great promise for completely individualized performance based simulation.

Early in the 1970s the concepts of System Approach to Training (or Instructional System Development) were accepted by the Operating Commands and seriously applied in developing training requirements. It is clear that in the future, simulation requirements will be determined during a total Instructional System Development Program and will be applied in a continuum of training programs and equipment that range from the academic to the flying environment.

B. MODIFICATION POTENTIAL OF EXISTING SIMULATORS

Since the present USAF inventory of simulators is the result of acquisitions made at various points in the evolutionary process, it is useful to categorize them as follows:

1. Very old devices using alternating current analog computers and no motion systems (mid 1950s) (B-52, KC-135),

2. First generation direct current analog computers, no motion (late 1950s) (F-106),

3. Second generation d.c. analog machines with early motion systems (early 1960s) (C-130, F-4),

4. First generation digital computer simulator, updated motion devices (mid 1960s) (F-111A, F-4E), and

5. Modern general purpose digital computer simulators with good motion but not latest state-of-the-art (late 1960s and early 1970s) (C-5, A-7, FB-111).

Figure II-1 is a pictorial showing these classes arranged along the horizontal axis of a three dimensional axis system. Computational sophistication, especially as represented by the advent of the digital computer, has been the key to growth into the other dimensions of motion and visual representation.

The very old devices are extremely difficult to augment. The computers utilize hardwired mathematical models which are totally inadequate to drive either motion systems or visual devices. The cockpits and instructor areas are large, heavy and not stressed to withstand a motion system. Augmenting these trainers (e.g., B-52), therefore, requires a new development effort with schedules consistent with such programs. It is possible to update for aircraft changes or to change the program use. The same considerations apply to early d.c. analog devices.

It is possible to add state-of-the-art visual devices to second generation d.c. analog simulators by adding small digital computers to correct deficiencies in flight characteristics. In some cases the existing motion systems do not have the weight capacity.

All of the digitally driven simulators can be modified to add visual devices and more modern motion systems if needed. In addition to motion systems, other somatic cue devices such as g-seats and g-suits can be added. In general, visual systems should not be added to simulators without motion systems. Starting with Class 4 simulators, computational flexibility is sufficient to consider the merits of modification to open the way to a vast new training task domain offered by visual simulation. Figure II-1 lists the additional training tasks made possible for simulation by the incorporation of adequate visual systems. Each system must be examined carefully, however, to assure that other factors do not mitigate against modification as a superior choice to replacement in a cost-effectiveness sense.

FLIGHT SIMULATOR DEVELOPMENT

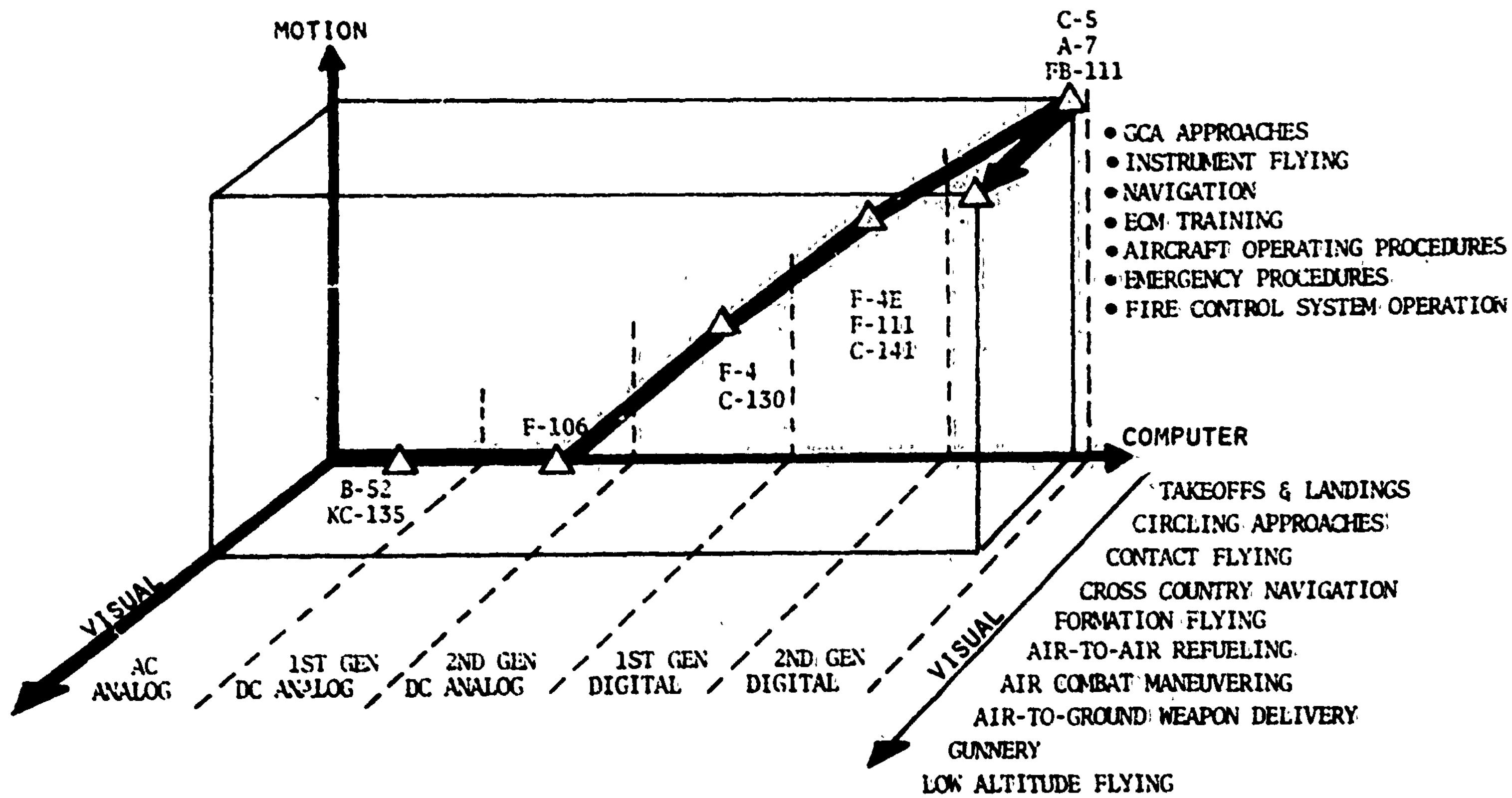


FIGURE II-1

C. SIMULATOR TECHNOLOGY STATUS

1. Visual Systems

As noted previously, a key element in increasing the use of simulators in aircrew training is the development of adequate visual systems to extend their use into mission segments formerly reserved for aircraft. Visual simulation in the Air Force has been deficient in meeting some Command requirements due to the nature of the military mission and the inherently incompatible combination of wide field of view and high resolution required in the visual scene. Air-to-ground weapon delivery, for example, requires the pilot to be able to look throughout his entire visible field of view during a circling attack on a target. The human eye has extremely high resolution within a limited field of view and can be directed anywhere within a wide area. Since visual simulation hardware normally has a fixed field of view, it may be necessary to provide very high resolution over a wide field of view. Certain missions, such as air combat, require extremely good resolution, possibly approaching that of the human eye itself. The exact simulator fidelity requirements remain a human factors problem requiring further research. Many missions, on the other hand, can be accommodated with relatively narrow fields of view such as the terminal phase of the final approach in landing. A 36° x 48° field of view with a six-arc-minute resolution is typical of visual simulation hardware used by the airlines. The Air Force has advanced the technology toward meeting the field of view, brightness, and resolution goals. Figure II-2 indicates the key subassemblies from which typical visual simulation systems are composed. The four basic functions involved are image storage, image generation, image relaying, and image display.

Two basic classes of image display are available for visual simulation. These are (1) the virtual image type in which the pilot sees the terrain and/or targets at optimal infinity, and (2) the real image type in which the displayed imagery is viewed on a screen or cathode ray tube (CRT).

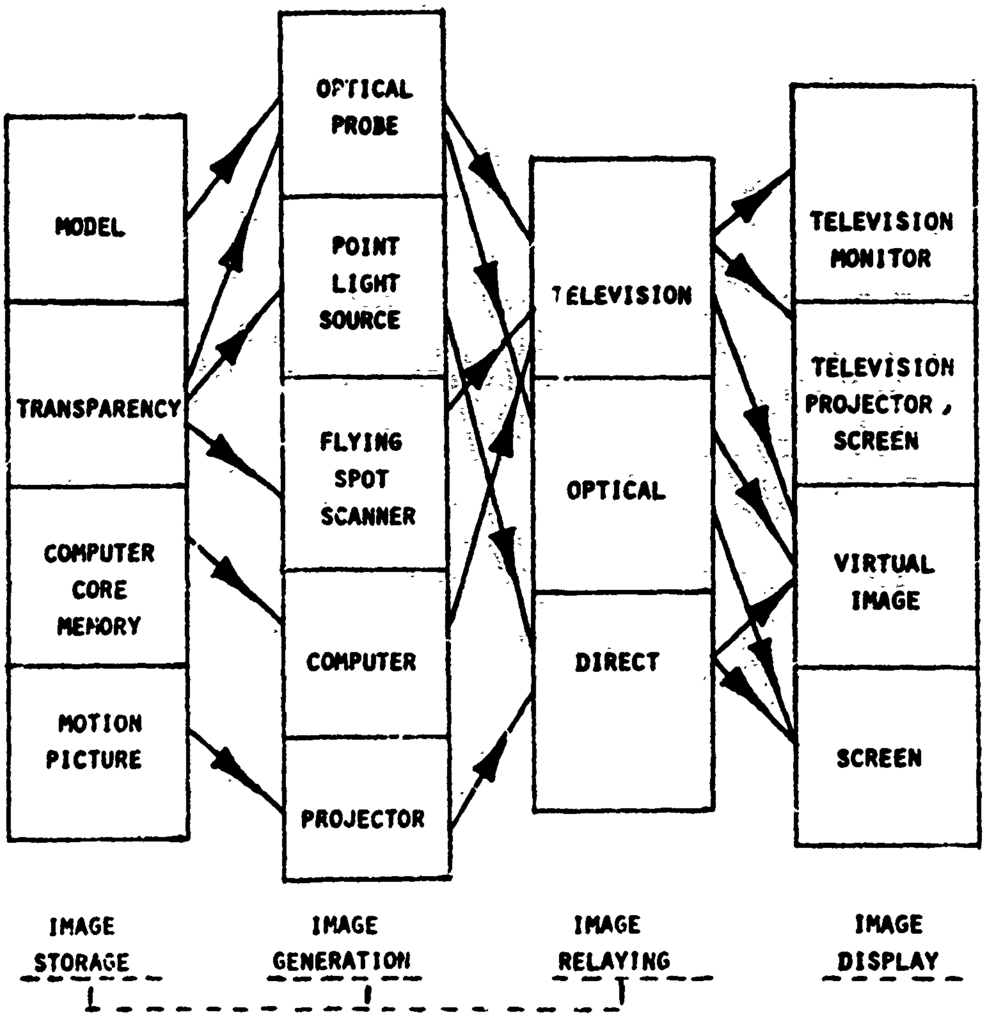


FIGURE II-2. VISUAL SIMULATION SYSTEM ARCHITECTURE

a. Virtual Image Display Systems

(1) In-Line, On-Axis Virtual Reflective Display

The system, normally referred to as the Farrand pancake window, consists of a spherical beam splitting mirror, a flat beam splitter, two linear polarizers, and two quarter wave plates. The image is formed on either a rear projection screen or a direct view cathode ray tube directly behind the optical elements. It passes through the spherical beam splitter and is reflected off the flat beam splitter back to the surface of the spherical beam splitter. Optically, this is the same as if the image were input at the focal plane of the spherical beam splitter, at a distance of half its radius. The viewer positions his eye at the origin of the radius and views the image at infinity. He is prevented from looking directly through the beam splitting optics to the input by the polarization of the imagery. This type of display has several significant advantages. The most important is that it allows a wide field of view and can readily be mosaicked for even wider fields of view. Farrand has proposed a display in the form of a dodecahedron or a twelve-sided figure made up of equal sized pentagons. Activation of eight sides or facets of the dodecahedron provides a display with little loss of normal fighter type cockpit viewing as on the SAAC.

The limitations of this type of display are low light transmission and unwanted reflections or "ghosts" which are not completely extinguished by the polarizers. The low transmission requires high brightness input CRTs to ahcieve 6 foot lamberts highlight brightness on the SAAC and ASUPT systems. The unwanted reflections typically fall within the range of 0.5 to 5.0% of the wanted image brightness and do not appear at infinity when compared to the wanted image. Comments from pilots indicate that these reflections are unnoticeable when flying the simulator except in a high contrast night scene.

The choice of image generator with these multi-channel mosaicked displays is important. The image generator must be capable of providing several channels of video from the same viewpoint with overlapping images. These images must be stable in order to minimize discontinuities between the image on adjacent channels. The ASUPT simulator employs digitally computed visual imagery and the SAAC employs an analog computed visual imagery to meet these requirements.

(2) Folded, On-Axis Reflective Display

This type of collimated display consists of a diffuse screen located at the focal surface of a spherical mirror with the viewing position located at the center of curvature of the spherical mirror. A beam splitter is inserted in the optical path to allow the input screen to be folded out of the viewing path. The image can be inserted into the display by means of a television projector and rear projection screen or by means of a cathode ray tube (CRT) whose diffuse phosphor screen is located physically at the focal surface of the spherical mirror. The more commonly used image input device is the cathode ray tube, which may be either a monochrome or color type tube. This type of display, because of geometrical interrelations between the spherical mirror and the beam splitter, has a limited vertical field of view, usually on the order of 30-36 degrees. The typical field of view produced by this type of display is 36° vertical by 48° horizontal. This type of display is frequently used on commercial airline simulators due to its compact size, low cost, and its ability to be utilized in front of both the pilot and copilot viewing positions. The commercial multi-channel version of this type display produced by the Singer Company is known as the Wide Angle Collimated (WAC) window. Other simulator manufacturers have comparable displays sold under their individual trade name, for example the Redifon "Monoview". An increased field of view capability can be achieved by stacking multiple displays, and a mosaic of six such displays (2 vertical and 3 horizontal) has been fabricated to produce a 48° vertical by 108° horizontal field of view for the F-4E #18 simulator.

(3) Off-Axis Reflective Display

This type of system is approximately the same as the folded on-axis reflective display. The beam splitter however, is eliminated and the image source and the viewer are located somewhat off the major optical axis of the collimating mirror, thus introducing a limited amount of optical distortion. The "Duo-View" display built by Redifon is the primary type of off-axis infinity image display currently in use. With a 50°-60° diagonal FOV and a large exit pupil[1] achieved by the use of very large mirrors, side-by-side veiwing is possible. However, unlike the flat screen/projector system, perspective

[1] "Exit pupil" refers to that area in which the viewer can get an intelligible view of the displayed information.

is very nearly correct for more than one crew position. While matrixing of these displays to provide a wide field of view has not yet been accomplished, Redifon is currently researching the problem and hopes to demonstrate this capability in the near future. The Duo-View is currently utilized by various airlines and the Air Force. Air Force installations of the Duo-View include the C-5/C-141 simulators at Altus AFB, the AWACS simulator currently being procured, and the AFFDL engineering simulators at Wright-Patterson AFB.

(4) Refractive Image Display

These displays utilize large refractive lenses (usually plastic) to collimate the input imagery. Both monochrome and color image input devices can be used with this type display. Lenses required with this type of display can become very large in size and quite heavy, and for these reasons the lenses employed are generally simple lenses. The use of simple lenses generally results in color fringes being visible in the display which can distract and detract from realism in the simulation. The requirement for large lenses also means that the individual channel field of view is narrow, usually on the order of 36° vertical by 48° horizontal. The field of view can be increased by stacking multiple displays, but is difficult to accomplish in an acceptable manner. The basic display is relatively inexpensive, but because of the characteristic color fringing, this type of display is not widely utilized in simulation applications.

b. Real Image Systems

(1) Flat Screen Projector

This TV projector/flat screen type display system utilizes either a front or rear projection screen to display an image at a finite distance in front of the simulator flight crew (usually 6 - 12 feet). It usually provides a nominal 50°-60° diagonal FOV. Although this type of display does not offer the fidelity and realism of infinity viewing devices such as the pancake window or mirror/beam splitter display, the matrixing of screens for wide FOV and side-by-side viewing is possible. Proper viewing perspective can only be offered for one crew position but an otherwise intelligible view of the display is available anywhere within the cockpit. Although these displays are used on the Navy 2F90 ADM training device, none are currently in use by the Air Force. The major objection to their use in Air Force simulators is the lack of realism caused by the real image (non-infinity) presentation and perspective errors which occur if more than one viewer or large head motions are involved in the simulation.

(2) Spherical Screen

The visual display system on the LAMARS (Large Amplitude Multi-Mode Aerospace Research Simulator) is an example of the spherical screen display. This display consists of a 20-foot diameter sphere mounted on a motion system with the pilot's eye at the center of the sphere. A monochrome television projector is located close to the pilot's head to project a target aircraft or terrain information on the spherical screen. A point-light source transparency projector, as described elsewhere, is located well behind and above the pilot to provide sky/horizon images and fills a larger portion of the sphere with more imagery than is possible with the TV projector. The television image is considerably brighter and is clearly visible when projected over the terrain sky image. The total field of view is ±138° horizontally and +108°, -40° (or as limited by the cockpit) vertically. The projected television image is typically 60° on the diagonal. Smaller fields of view with higher resolution are possible by changing projection lenses.

c. Image Generators

The image generator (IG) generates and provides electrical or light signals to the display subsystems. These signals are then transformed by the display into a visual scene similar to that encountered in flight. This scene is continuously updated to represent changing aircraft position and attitudes.

The IG receives flight parameters from the simulator describing the simulated aircraft position and attitude. Using these data, the appropriate imagery is extracted from the image storage (see Figure II-2). This imagery is processed, special effects such as visibility and fading are added, and the results relayed to the display. The image storage may consist of a three-dimensional relief model, film transparency, numbers in computer core or motion picture film, as illustrated in Figure II-2. The image extracted from storage is that portion which the pilot can see at one time while the stored image can be orders of magnitude larger. The following sections describe the IG technology which is currently available.

(1) Full Raster Scanned Computer Image Generation

The Computer Image Generation (CIG) technique takes advantage of the memory or storage features of the computer to store visual scene content in the form of numbers. The scene consists of surface patterns or objects formed by planes of different brightness levels which are in turn bounded by straight lines called "edges." The number of edges in a scene is a relative measure of image content and CIG system performance. The raster scanned display is produced from video signals generated from the computer output and, while stylized in character, is similar to the real world scene. The total stored environmental data base utilizing conventional computer storage techniques such as magnetic discs, tape, etc., may be much larger than the working storage. The ASUPT computer image generation system represents an advancement in the state-of-the-art over the only other CIG system now being used; the 2F90 ADM aircrew training simulator located at the Naval Air Training Station at Kingsville, Texas. This latter system is currently being used by the Navy to evaluate visual simulation in the Navy flying training program.

The principal advantages of the CIG approach are exact perspective, moving object generation, quick change of the scene content, unlimited altitude, attitude and rates, large area of flight coverage, and ease of multi-channel image generation. The system also requires less space and building height than the terrain model-board approach. Disadvantages include limited scene content due to limitations in the working storage and processing capability and the resulting stylized appearance of the scene. The ASUPT system which employs this technique will be used by AFHRL to gain insight into the ability of this system to train students in undergraduate pilot training. The training tasks will include:

- Taxiing,
- Takeoff and climb out,
- Overhead approach pattern and landing,

- Airwork and aerobatics,
- Formation flight,
- Navigation, and
- Night flight.

The Navy CIG system has been interfaced with the 2F90 trainer. This system has a 500 edge processing capability, a 500 edge data base, a three channel color display and fading to the horizon. The ASUPT system was designed and developed as a part of a total training research simulator. This system has a 2000 edge processing capability, 3 levels of detail, a 600,000 edge data base capability, fading to the horizon, 7 channel monochrome display, edge smoothing, curved surface shading and edge sharing between two cockpits.

(2) Calligraphic/Night Only Systems

This concept in visual image generation, a variation of computer generated imagery, has evolved over the past several years into a highly acceptable means to generate a realistic night representation of an airfield area. Scene detail includes horizon glow, runway markings and airfield light-points (including VASI and approach strobes). The calligraphic generation technique is totally different from the raster scan method utilized in full day/night CIG systems. With the calligraphic technique, the electron beam is moved directly from one computed light position to another and is turned on only at those positions. In lieu of the usual shadow mask color CRT, beam penetration type CRTs are utilized. Color is controlled by the intensity of the electron beam. Color rendition is limited to red and green and the spectrum between. Several display channels can be utilized to give a wide horizontal field of view. Advantages of these systems are: relatively low acquisition cost; high MTBF and low MTTR; no additional facilities requirement; and the capability to readily change from one airfield area to another. One disadvantage is that in order to maintain resolution, reliability, and simplicity, only beam penetration CRTs can be utilized. This currently rules out utilization of video projectors and limits the display to the folded, on-axis reflective type. Night-only systems are currently in use by several airlines.

(3) Analog

Analog systems provide low detail ground plane and horizon information to the pilot. A current example of analog system is the Synthetic Terrain Generator (STG) on the SAAC. This system fills the entire FOV with a matrix of 1/2 nautical mile squares, similar to a checkerboard, that represent the ground plane, a horizon, and the sky. The squares are displayed in four shades of gray with a haze generator that reduces the contrast of the squares as range increases. Unique symbols in the ground plane provide geographically fixed reference points. The STG system provides the pilot with cues to his attitude, altitude, heading, velocity, and position with no maneuver restrictions. This type of system may be used by itself or may be used to augment an area of interest system.

(4) Area of Interest

State-of-the-art image generation systems cannot fill the full field of view (FOV) of a very wide angle visual display with detailed imagery. To best utilize the smaller FOV with detailed imagery, the area of interest (AOI) approach was developed. This approach moves the small FOV detailed image in azimuth and elevation throughout the wide FOV display. The AOI may be mechanized to follow either the line of sight from the pilot's eye point to some preselected geographic location or, utilize some suitable head position sensing system to follow the direction in which the pilot is looking. Either approach allows the pilot the freedom to maneuver the simulator about the AOI (i.e., a ground target or airfield) with very few restrictions. AOI systems using a preselected geographic location have been demonstrated, but a system using pilot head sensing has not.

(5) Model Board Television

One basic technique which has been developed to a high level of sophistication is the terrain (model) board for image storage, the optical probe and television camera for image generation, and a variety of display techniques. The optical probe and television camera "look" at the scale terrain model according to aircraft position and attitude, with the video information thus generated representing the real world visual environment. This information is then displayed to the pilot in the simulator.

Visual simulation systems employing optical probes and scale terrain relief models are currently being manufactured by several firms, including Redifon, The Singer Company, and CAE. The e devices possess narrow field of view capabilities, usually on the order of 60 degrees on the diagonal, and exhibit depth-of-field limitations at low altitudes. The commercial airlines are using these visual simulation devices due to the relatively simple nature of the visual portion of their training programs and the similarity of aircraft involved. The Air Force, however, is faced with the situation where visual simulation is required for training in complex and diversified missions involving a wide variety of dissimilar aircraft. The capabilities provided by narrow field-of-view visual simulation devices cannot fulfill total Air Force requirements for training, since in many cases a wide field of view is essential. When the original exploratory development programs for camera/model visual simulation were initiated, the Air Force had just completed the installation and evaluation of the type SMK-23 visual simulation system which was subsequently determined to be unsuitable for training. The major difficulties centered around poor image quality principally caused by depth of field limitations in the optical probe and the low band pass of the television system. A subsequent study discovered a technique which was later exploited in a development program to fabricate an engineering model of an optical probe. This program demonstrated that an essentially infinite depth of field could be achieved from an optical probe. Subsequent improvements in video techniques coupled with the optical probe improvements have resulted in highly acceptable narrow angle (48° horizontal x 36° vertical) visual systems. With the basic electrooptical problems of camera/model image generation essentially solved, attention was focused on the problem of extending the field of view capability of such systems. Another development program was conducted and an engineering feasibility probe exhibiting a 140° field-of-view, excellent resolution and infinite depth of field was produced for monochrome systems. This probe required sophisticated computer controlled manipulation of servo driven optical elements. Further work in this area is required before the full capability of these probes will be realized.

This stage of the development program represented the first phase of a total wide-angle camera/model visual system. It was then necessary to convert this real imagery into the form of high quality television video information. The capabilities of the optical probe were matched through the use of a combination of a large (2 inch) vidicon tube, and a magnifying image intensifier was used to pickup and transmit the imagery. In order to preserve the high resolution information being produced by both the optical probe and the television camera, the wide-angle display to be used in the visual system will undoubtedly be comprised of a mosaic of input channels. It was then necessary to develop video processing techniques which would provide the proper wide-angle display input formats so as to result in an accurate reconstruction of the field of view produced by the wide-angle optical probe. The remaining subsystem of the developmental wide-angle camera/model visual system, the wide-angle display, will be developed during a research program, concurrently under formulation, to provide for the development of a holographic in-line infinity display.

Recent improvements in modeling techniques have greatly enhanced the realism of camera/model systems. Additional new modeling techniques, pioneered by Redifon Flight Simulation, Ltd., now make it possible to realistically create takeoff and landing model boards at a scale of 4000:1, thus, greatly reducing facility size and lighting power requirements.

A technique of simulating another aircraft in the visual field of view utilizing a gimbal mounted aircraft model and high resolution monochrome television camera was perfected in the SAAC program.

Virtual image display systems such as the Redifon Duo-View and the mirror/beam splitter (WAC window) are the types most widely used today with camera/model terrain image generators. The more economical flat screen/projector type displays are also used but do not offer the infinity viewing and correct perspective as do the virtual image type. All of the above systems are basically limited to a maximum field of view of approximately 36° vertical by 48° horizontal. In order to facilitate the display of the wide field of view information offered by some probes, matrixing of several basic display units is required. The F-4E #18 visual system utilizes a matrix of WAC windows. Redifon is presently pursuing an internal development effort in order to matrix multiple Duo-View displays. Several Air Force in-house development programs will continue investigating methods of displaying wide fields' of view for multiple crew, wide body aircraft cockpits.

(6) Transparency/Point-Light Source

The LAMARS at AFFDL is the most recent example of this technology. The transparency consists of two small transparent hemispheres which have images of a featureless brown earth, a clear blue sky with occasional clouds, and a well defined horizon. Inside these hemispheres, two point-light sources are positioned in accordance with the x, y, and z coordinates of the simulator so that the projected horizon is always correctly located without distortion. The entire assembly is then rotated about the three axes to provide roll, pitch, and yaw. The image on the transparencies is displayed to the pilot on the inner wall of a spherical screen. This approach provides the pilot with attitude and heading cues but very limited altitude and no linear velocity cues.

d. State-of-the-Art Visual Systems

(1) Simulator for Air-to-Air Combat (SAAC)

The SAAC Advanced Development Program grew out of a 1965 TAC requirement to develop a one-on-one air-to-air combat simulator. In 1971, a three-window breadboard visual system was demonstrated at ASD and a contract was let for the full two-cockpit SAAC system in early 1972.

The SAAC system consists of a two-cockpit simulator complex, each cockpit and its visual display mounted on a six degree-of-freedom motion base. The simulators represent non-slatted F-4E aircraft and allow one-on-one air-to-air combat with AIM-7E radar and AIM-9J infrared missiles, and 20 mm cannon. At the operator's console, an Air Combat Engagement Display provides a 2-D representation of the 3-D air-to-air engagement on a CRT for monitoring and evaluation. A record/playback system allows all systems to be played back for later evaluation.

The SAAC visual display system is an eight channel mosaic of pentagonal "Pancake Windows" to provide a field of view of + 148° horizontally and + 150°, - 30° vertically. The input for the display is a dual raster, monochrome TV system using one raster for the background terrain/sky and one raster for the opposing aircraft. The background terrain/sky is a contact analog checkerboard terrain providing attitude, heading, altitude, and velocity cues and, with symbols in the terrain, geographic location. The target aircraft image generator is a gimballed model aircraft viewed by a TV camera. The SAAC is located at Luke AFB, Arizona.

(2) Advanced Simulator for Undergraduate Pilot Training (ASUPT)

The ASUPT visual simulation system consists of a Computer Image Generation (CIG) system and a seven channel, in-line, on axis optical display with a FOV of approximately 280° horizontal and 140° vertical. (Image generation features of this simulator have been described previously). A moving aircraft model is a feature which permits training in formation flight. This moving model represents a T-37 aircraft which is moved in accordance with outputs from the simulator. The display system completely surrounds the student and instructor pilots. This system required development of large optics and the world's largest CRT (36 inch). The ASUPT system is located at AFHRL/FT, Williams AFB, Arizona.

(3) F-4E Number 18 Simulator

The F-4E Number 18 simulator is an F-4E simulator with a developmental visual system for air-to-ground weapons delivery and takeoff and landing. This color visual system utilizes a six channel mosaic of WAC windows with a FOV of 108° horizontally and 48° vertically. The image generator uses a 1500:1 scale model board and a 120° wide-angle probe.

This system has been installed at Luke AFB and is to undergo an OT&E program in FY 76.

(4) C-5/C-141

The visual systems attached to the C-5/C-141 simulators at Altus AFB, Ok, currently represent the only visual systems in the Air Force inventory being actively employed solely for training purposes. The visual systems are of the camera-model type, and provide out-the-front-window training for visual takeoff, approach, landing and taxiing, along with transition from instrument to visual flight operation. This "limited visual system" is essentially a special purpose Redifon system and it employs the Duo-View type display. The system operates in full color and presents a 36° vertical by 48° horizontal field of view for both the pilot and copilot simultaneously. Day, night, and dusk conditions are simulated, and the terrain board is specifically configured to include terrain, airfields, and airfield lighting unique to Air Force training situations.

(5) Large Amplitude Multi-Mode Aerospace Research Simulator (LAMARS)

The visual simulation system on the LAMARS consists of a sky-earth projector, television camera/model, television projector and spherical screen. The simulator pilot's viewing position is in the center of the spherical screen to avoid distortion of his view of the projected images. The sky-earth projector consists of two hemispherical transparencies with two point-light sources located inside the transparencies. This projector is located at a considerable distance from the center of the screen. To provide the pilot with the proper perspective and undistorted image, the point-light sources move within the transparencies. The television projector is also located off-center of the screen. The projector provides either a 60° diagonal or 15° diagonal field of view image on the screen by means of lens changes. The input video to this projector is generated either by a conventional model board/probe/television camera system or an air-to-air target image generator. The air-to-air target aircraft model is encapsulated in a clear plastic ball. This ball is then viewed by the television and is rotated to generate the pilot's line of sight attitude between the two aircraft. This system is installed at the Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio.

2. Motion and Force Cues

By the end of the 1960s, there was general agreement in industry and Government that motion cues are required for certain types of flight simulation problems. By the early 1970s, the 6-Post geometry, six degree-of-freedom motion system had gained widespread acceptance by both the airlines and Government agencies as a relatively low risk, cost-effective means to provide motion cues. The 6-Post system avoided concern as to which degrees-of-freedom were necessary for a given simulator. Additionally, the 6-Post configuration offered advantages in commonality of parts (each system utilizes six identical actuators) and the greater component accessibility offered a maintenance advantage over the cascaded type systems. A hardware problem which remained with the 6-Post system, however, was the discontinuity in the force imparted to the crew members when any of the actuators reversed direction of travel. This discontinuity is due to the additional force needed to overcome the effects of stiction and varies in magnitude in operational systems from about 600 lb to 250 lb force depending on specific actuator design and system hydraulic pressures. This stiction effect, widely colloquialized as "turn around bump", manifests itself as a false cue in the training environment, and as such has been a source of distraction in applied motion cueing. A promising solution to this problem is being pursued by the Singer Company. The Singer Company is developing a mass producible motion system with low friction actuators yielding breakaway forces below 100 lb.

The amount of motion excursion, velocity, or acceleration required for training is not supported by a good research data base, nor has it yet been determined how best to take advantage of the capabilities available in a given motion system. Much research remains to be done in this area. The motion system requirements specified in MIL-STD-1558, is the product of engineering judgment and experience in the art of motion simulation, and represents a good compromise between cost and utilization risk for most training flight simulator applications.

During the early 1970s, progress has been made in developing viable alternate or augmenting methods for providing motion cues. These include simulator g-suit and g-seat systems. The g-suit simulation system provides the mechanization and drive control necessary to properly control the pressure in the crew member's anti-g-suit system. Activation of the system provides the crew member with familiar body sensory cues of the instantaneous and sustained "g" forces acting on the simulated aircraft. The g-seat system is comprised of compartmentalized seat pan and backrest cushions with an active lap belt subsystem. The seat pan and backrest consist of mosaic arrangements of pneumatically driven cells controllable in position. The lap belt subsystem contains a pneumatically driven piston which provides a controllable tensile force on the lap belt. The drive concept for the g-suit system is relatively straight forward; suit inflation is proportional to the specific acceleration (g) acting upon the simulated aircraft. The drive concept for the g-seat system, however, is little better than exploratory. The g-seat imparts cues by contouring the seat to vary the pressure distribution on the pilot while displacing him vertically and/or longitudinally and by tilting the seat pan and/or backrest planes. The lap belt force drive must be coordinated with the seat and backrest drive. The possible combinations of g-seat subsystem drives is virtually limitless and further confounded by the requirement of coordinating the g-seat drives with motion system and visual system drives. Reliable models of how the human somatic sensors operate independently and in conjunction with the vestibular and visual senses would be invaluable in this regard, but do not exist. Additional research is warranted in this area.

Another type of motion cueing system is the Vibration/Buffet System. These are typically small displacement, high frequency motion systems which are utilized to provide the higher frequency vibration and buffet cues either in the absence of or as a complement to the larger scale motion systems. These are desirable where the visual system design precludes the incorporation of a larger scale motion system (such as NASA Langley Research Center's Differential Maneuvering Simulator (DMS)), or where it is undesirable to buffet the total cockpit/visual system complex (such as SAAC). These systems are typically capable of providing acceleration cue levels up to ± 1 g vertically at frequencies up to 20 Hz but with a total displacement on the order of 2 inches. The general drive philosophy is to subject the simulated cockpit seats to the same vibration environment as would be encountered on the aircraft being simulated in the same flight condition. Given the necessary aircraft data, this drive concept can be readily implemented.

3. Sensor Simulation

The following basic sensor system types are relevant to current Air Force simulation for aircrew training: radar, infrared (IR) and low light level television (LLLTV).

a. Radar Simulation

The only area of sensor simulation in which the Air Force has made significant progress is radar simulation. The majority of such equipments (A-7D, C-5A, F-111, F-4, B-52, B-58) utilizes the light optic (transparency) technique. Basic source data from air target charts are encoded by a photographic process producing a transparency which permits light to pass in proportion to the reflectivity and elevation values of the elements of the scene. A basic limitation with this approach is that the detail of information content in the data base is not sufficient to provide simulation of a high resolution radar system. There are significant difficulties associated with improving the data base: cultural data are encoded with only the basic outline shown as area return at approximately 500 feet resolution and terrain contour spacings vary from 100 feet at the lower elevations to 600 feet at higher elevations. The transparency technique cannot be rapidly updated. These problems have caused the Air Force to develop a digital technique which encodes all the cultural and terrain information in digital format. Current programs which have incorporated the digital technique are the Undergraduate Navigation Training System (UNTS), the Navy 1D23, and the German Air Force F4F Simulator (a foreign military sale). The problem of improved resolution still remains with these systems since the basic source data does not have sufficient cultural information. Two significant activities are currently underway to improve radar simulation capability: the Defense Mapping Agency (DMA) has developed a new off-line digital data base with cultural and terrain information encoded at various levels of resolution. To date, they have encoded approximately 200,000 sq. NM. The basic difference from the previous data base is that cities and towns are now defined as to their cultural content. The Air Force has an engineering development program under PE 64708F (Project 1183) in conjunction with DMA's program, which will produce high resolution digital radar landmass (DRLMS) processing hardware/software for subsequent evaluation by TAC and SAC in an F-111 simulator to determine the adequacy of the two activities.

b. Infrared and Low Light Level Television Simulation

Current Air Force simulation capability for these sensors is extremely limited with respect to providing adequate crew training. The B-57G Rear Seat Operational Trainer was the Air Force's first operational device and it provided a very limited simulation of electrooptical (EO) sensors. It used an optically scanned film strip and the resultant video was displayed on a CRT. The film was made from a recording taken from an actual B-57G flight. Some targets were added artificially. The simulated flight path was limited to that of the aircraft and sensor position and control settings. The Functional Integrated System Trainer (FIST) was developed as a part task trainer for three of the AC-130 Gunship system operators. This included EO simulation consisting of a film plate taken from an aircraft flight which was optically scanned and the video displayed.

Recent emphasis has been placed on investigating the various applicable techniques (terrain model board, film strip and computer image generation) to satisfy the training requirements. As a result, a multi-phase exploratory development program was established. The first phase consisted of the collection of actual EO sensor data in and around Eglin AFB and the analysis of this data to determine the important characteristics of the sensors and related phenomena. A second effort was the development of nonreal time CIG models of the three Eglin AFB target areas. The emphasis during these efforts was on the simulation of cultural features.

As a result of discussions with SAC, primarily in support of the B-52 Instructional System, a contract was let to model some typical scenes using CIG technique of predominantly terrain topography since the primary usage of the EO system on the B-52 was for terrain avoidance. This effort will be complete by October 1975. In late 1974, efforts were made to utilize the Project 1183 Off-Line Digital Data Base (developed by DMA) to generate an orthographic view of the highest resolution area (1 sq. NM) of Las Vegas. A follow-on effort to further refine this approach, update the diurnal cycle curves and correlate the results with actual infrared imagery will be complete by October 1975. An in-house effort consisted of the modification of a SMK-23 model belt to represent infrared imagery. This model belt was driven past a TV camera with different filters to represent time of day changes and displayed on a TV monitor. A preliminary evaluation was conducted by SAC in April 1975.

4. Electronic Warfare Simulation

Electronic Warfare is divided into three distinct areas: Electronic Countermeasures (ECM), Electronic Counter Countermeasures (ECCM) and Electronic Warfare Support Measures (ESM). Most aircrew simulators being procured by the Air Force provide some form of electronic warfare simulation. This simulation is primarily in the area of ECM and in special cases, ESM. The typical elements of ECM/ESM simulation is illustrated in Figure II-3. ECCM simulation is similar, however, it is more oriented to an internal equipment counteraction instead of an operator's reaction. A firm requirement for ECCM simulation has yet to be developed by the Major Operating Commands.

The data base contains the information with respect to threat location and parameters (frequency, pulse width, pulse repetition frequency, etc.) pertinent to the problem. The data is then modified by the environment and receiver simulation characteristics (distance and bearing from threat, antenna pattern, etc.). The received power, bearing and signal characteristics are then processed and displayed on the student's display. As the student observes the information presented, he then becomes a part of the loop. In the case of ESM, the student will manipulate his individual controls, record or note the various characteristics observed and pass the information to an external source. For this type of simulation the

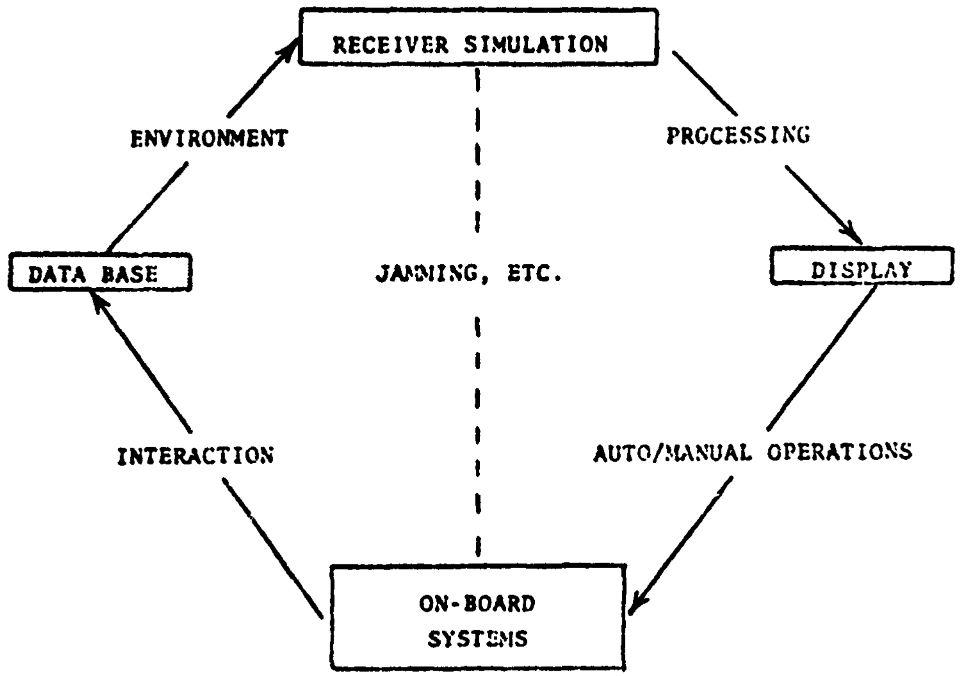


FIGURE II-3. ELEMENTS OF ECM/ESM SIMULATION process stops. In the case of ECM, the student provides an input to the process based on the information displayed. He may use his on-board systems, activating jammers, chaff, flares, and etc. This may then cause a reaction of the data base, i.e., change in frequency. At this point the loop would then be reprocessed.

Various forms of electronic warfare simulation can be found on mission simulators such as the F-111, F-4 and A-7. This simulation, however, is limited to air and ground targets, jamming, and chaff drops as would be seen on a tactical radar scope. Its primary concern is with making the operator familiar with what ECM is and how it appears on the radar indicator. For the B-52 and other systems which incorporate a defensive position a much more elaborate simulation capability is provided. Present EW officers in SAC are trained on analog systems such as the AN/ALQ-T-4 and T-3 simulators. These simulators provide a signal environment which allows the student to activate all on-board systems. These devices provide full aural and visual indications of the various emitters. These simulators, however, are 1960 vintage and will eventually be replaced by digital simulators, such as the simulator for Electronic Warfare Training (SEWT). SEWT is a single system designed to train basic electronic warfare officers. The system consists of eight student stations and a general hardware configuration. The equipment layout in each student booth does not represent any particular aircraft configuration and is designed so that various equipments can be covered when not required for a mission. The equipment provided includes the latest jamming and receiving equipment in the Air Force inventory. Under control of the SEL 86 computer, the system can provide 1000 different emitters to each student over a normal mission. Each student is automatically monitored and scored during each mission. If a student errs, the system displays instruction on proper procedures automatically through a cathode ray tube display system in each student booth.

Rapid changes in the real world hostile threat environment along with the increase in the number of threats cause the most serious problems to simulation. Because the hardware must operate in the dense signal environment, a dense environment must be reproduced for the student. This is not really a technology problem, but more of a cost problem, since the cost of simulation increases as the number of emitters increases. The rapid changes in hostile threats result in changes in equipment and as such the simulation of these must be constantly updated to remain abreast of the hardware technology.

As changes occur in threat hardware, the trend in simulation also changes. Actually, the increase in signal environment may reduce the simulation problem, because of the increase in automation and display content of the electronic warfare systems. The information content and the interaction of the operator appears to be gradually reduced, such that a new concept of simulation may result.

5. Instructor/Operator Technology

Historically, instructor/operator stations were large hardware stations designed to be manned by two or more instructors and operators. The stations consisted of repeater instruments for each of the simulated aircraft instruments; controls for malfunction insertion, repositioning and environmental changes; individual indicators for monitoring the status of simulated aircraft systems and the exercise; and electromechanical plotters for a two-dimensional trace of the simulated aircraft. This approach to IOS design has resulted in systems characterized by complexity, high cost, low reliability, and a poor instructor to student ratio.

The historical IOS was a very complex station. Its physical size alone presented a major obstacle which had to be overcome before efficient training could be accomplished. Nonstandardization of input and control also added to the complexity of the station. Input and control of environmental conditions was accomplished with potentiometers; repositioning was accomplished with digital switches; some malfunctions were initiated with switchlights, while others were initiated with special purpose keyboards. A multitude of techniques were developed to perform two basic functions - input and control.

Due to its composition, the IOS was no more reliable than its components. Repeater instruments and electromechanical plotters, utilizing pre-1950 technology, had poor reliability. Of all the major components of a simulator, the IOS should have one of the highest reliability percentages but, in fact, has one of the poorest.

With the emphasis on hardware, the initial cost of the IOS was high. In addition to the high initial cost, support cost for the IOS was high especially when frequent replacement of expensive repeater instruments was required due to their inherent low reliability. Little attention was given to making hardware/software trades to reduce overall system costs.

The historical IOS had a poor instructor to student ratio. To be cost-effective, an instructor to student ratio should be at most 1:1. Two major programs which utilized the historical approach to IOS design were the F-111 series simulators and the A-7D simulators. The F-111 series simulators, built by Singer Simulation Products Division, have instructor/operator stations with repeater instruments, digital readouts, special purpose keyboards, digital switches and indicator lights. In fact, there are 94 digital switches, 56 large digital readouts, 248 small digital readouts, 309 switch lights, 484 indicator lights and 22 strip meters. Malfunction inputs are accomplished at the Malfunction Insertion and Display Unit (MIDU) which contains a lighted matrix display for malfunctions and uses two special purpose keyboards (21 letters and 12 numbers) for malfunction insertion. The IOS was designed as a two-man station with the capability for use by three men. The main plus factor for the F-111 IOS was in keeping the instructor to student ratio at 1:1. The A-7D simulators, built by Conductron (McDonnell Douglas Electronics Company), similarly have instructor/operator stations with repeater instruments, digital readouts, switch lights, potentiometers, digital switches, and electromechanical X-Y plotters. In the A-7D system, instruments and subsystems are grouped individually, and input and control is accomplished from the individual panel for the subsystem (no common malfunction panel as in the F-111). The A-7D IOS was also designed as a two-man station and the instructor to student ratio is 2:1. At the present there is a need to develop a compact hardware station where one man can accomplish the tasks which required several men in the past by shifting the emphasis from hardware to software. Current state-of-the-art advancements have enabled the development of a compact, one-man hardware station, complemented by sophisticated software which eases the task loading of the instructor. Software is used for preprogramming simulator missions and malfunctions, on-line alteration of any simulation variable, monitoring student progress, and even limited scoring of student performance. Software today is enabling computer aided instruction without instructor intervention, in the form of prerecorded automated demonstrations. We are rapidly approaching our desired situation where we have one instructor training several students efficiently.

The current state-of-the-art technology can best be discussed by dividing the IOS components into the hardware and software categories.

a. Hardware Technology

The major hardware advancement in instructor/operator stations has been in the use of Cathode Ray Tube (CRT) display systems to replace the vast majority of repeater instruments, indicators, digital readouts and electromechanical plotters. This substitution is possible since information can be displayed on a CRT only when it is necessary. The CRT is a very flexible display device which is readily adaptable to meet changing requirements for information content, placement, and format. Since one CRT display can be used for programming displays for input and control, status displays for monitoring, and graphic displays for aircraft tracking and precision approach monitoring, the use of CRT displays can greatly reduce the size of the IOS. They can also reduce the hardware cost of the IOS and improve reliability.

A hardware advancement which interfaces with the CRT displays is the general purpose keyboard used in conjunction with the CRT for input and control. The keyboard not only reduces the number of controls, but also reduces the complexity of the station by providing standardization of operation for input and control. Use of the general purpose keyboard with instructor/operator stations can reduce the station cost and improve the station reliability since they are of solid-state design.

Even with our current state-of-the-art technology, some individual indicators and controls are still required at the IOS. These indicators and controls are required mainly by systems or equipments involving the safety aspects of the simulator.

b. Software Technology

Software advancements in the area of instructor/operator stations include instructional and conversational software which eases the task of the Instructor/Operator (I/O), development of logical software which allows preprogramming of events and automated task sequencing, and development of specialized routines for monitoring student actions and scoring of student performance. In general, software is now accomplishing many of the tasks which required human intervention in the past.

There are several major programs which have utilized the current state-of-the-art technology in the design of their instructor/operator stations Among them are the CH-3E and HH-53 helicopter simulators, the Simulator for Electronic Warfare Training (SEWT), the Advanced Simulator for Undergraduate Pilot Training (ASUPT), the Army SFTS helicopter simulators, and the Navy 2F-101 jet trainer simulators.

The CH-3E and HH-53 helicopter simulators, built by Reflectone, Inc., utilize an advanced one-man IOS. The helicopter IOS has a CRT display system with a keyboard from which program setup and control is accomplished through the use of programming displays, monitoring is accomplished with the status displays, and performance is measured utilizing Ground Controlled Approach (GCA) displays and two-dimensional cross-country displays. Software allows preprogramming of events and a software routine automatically monitors and displays corrective information on GCA displays. The instructor to student ratio for the helicopter simulator is 1:2.

The Simulator for Electronic Warfare Training, built by AAI, also utilized an advanced one-man IOS. The heart of the IOS includes a CRT display system and a general purpose keyboard. From this station, one man monitors the simulation exercises being conducted in eight student booths. Software monitors student actions, and if necessary, initiates 'holding' error routines which allows the student to correct erroneous actions, and assigns a weighted score reflecting each student's performance.

A programmable CRT malfunction display and control is currently being installed in the C-5A Mission Flight Simulator. The first installation has been completed at Altus AFB.

c. Planning Issues for IOS Design

There are several key factors which must be addressed before the advanced instructor/operator stations can be employed to their full potential and be economically viable.

(1) First of all, the question of how many students can one instructor train efficiently, must be answered. The Army originally required an instructor to student ratio of 1:4 with their SFTS helicopter simulators. However, once training began, it became readily apparent that the task loading was too great for the instructor, and Engineering Change Proposal action was required to reconfigure the station for a 1:2 instructor to student ratio.

(2) A second question to be answered is how should the displayed information be presented to the man at the IOS. Since the CRT is a flexible display device, there are many ways in which information can be exhibited on the CRT. Human factor studies must be accomplished to determine when alphanumeric displays are required, when bar graph displays are required, or when pseudoinstrument faces are required.

(3) A third question to be answered is how much automation should be incorporated in the advanced IOS. We need to know how much automated monitoring, task sequencing, scoring, feedback, etc., can be cost-effectively included with the overall system. Too much automation may place our effectiveness of instruction in jeopardy due to student rejection.

Current research and development in the area of instructor/operator stations is now being accomplished with the ASUPT. The ASUPT has three instructor stations: a conventional IOS with repeater instruments, indicators, controls, etc.; an advanced IOS with CRT displays and keyboard; and an in-cockpit instructor station with CRT display and specialized keyboard. From studies with this simulator, the optimum design for the IOS can be determined as a result of direct comparison of IOS effectiveness.

6. Computer Technology

As discussed earlier, the rapid evolution of computer technology from analog to high capacity digital technology has facilitated higher fidelity and more comprehensive training simulator systems. General purpose digital computers have been incorporated on all recent simulators for aircrew training. Table II-1 identifies the computers used on several major training simulators.

The computer system performs the real time information processing functions which activate the simulator. Computed functions include flight, aerodynamics, engines, ballistics, and avionics to simulate performance of the weapon system. Additionally, instructional provisions are implemented by the computer to provide instructor control of the training situation. The expanded processing and storage capacities of modern general purpose computers have facilitated digital generation and processing of visual and sensor environmental stimuli simulation. Student performance

TABLE II-1

COMPUTATION SYSTEMS COMPENDIUM

TRAINING DEVICE	MANUFACTURER	COMPUTER	COMPUTERS/ SIMULATOR	LENGTH OF THE OPERATIONAL COMPUTER PROGRAM SYSTEM (WORDS OF CORE)
C-135B	SINGER	MARK I	1	NOT AVAILABLE
C-141A	CURTISS WRIGHT	CDC 924	2	38K
C-141A	SINGER (LINK)	SEL 840A	1	34K
F-4E	SINGER	CP4B (SINGER)	1	92K
C-5A	MDEC (CONDUCTRON)	SEL 840A/840MP	2	63K
F-111A	SINGER	GP4	1	92K
FB-111A (Bomb/Nav)	SINGER	SIGMA 5	2	88K
FB-111A	SINGER	SIGMA 5	3	180K
A-7D	MDEC	DC 6024/1	1	40K
HH-53C	REFLECTONE/SECOR	DC 6024/3	1	30K
CH-3	REFLECTONE/SECOR	DC 6024/3	1	30K
F-111D	SINGER	GP4B	2	194K
F-111F	SINGER	GP4B	2	175K
F-15	GOODYEAR	DC 6024/4	2	103K

TABLE II-1

COMPUTATION SYSTEMS COMPENDIUM (CONTINUED)

TRAINING DEVICE	MANUFACTURER	COMPUTER	COMPUTERS/ SIMULATOR	LENGTH OF THE OPERATIONAL COMPUTER PROGRAM SYSTEM (WORDS OF CORE)
T-37	SINGER	DC 6024/4	3/4	42K
T-38	SINGER	DC 6024/4	3/4	49K
B-52 (MOD)	SECOR	DC 6024/5	1	30K
SEWT (SIMULATOR FOR ELECTRONIC WARFARE)	AAI	SEL 86	1	50K
ASUPT (ADVANCED SIMULATOR FOR UNDERGRADUATE PILOT TRAINING)	SINGER	SEL 86	3	FLIGHT 83K VISUAL 32K (FORTRAN)
SAAC (SIMULATOR FOR AIR-TO-AIR COMBAT)	SINGER	SIGMA 5	4	80-100K (FORTRAN)
UNTS (UNDERGRADUATE NAVIGATION TRAINING SIMULATOR)	HONEYWELL MARINE SYSTEMS	HONEYWELL H 716	41/52	COMPLEX 51K 13 EA RADAR CONTROL 9K (1 TIME)

recording and automated flight demonstrations have been made possible and implemented with faster, higher capacity magnetic storage devices. The computer system is also configured and developed with appropriate software facilities to support the maintenance and changing mission requirements of the training simulator. Computer system technology incorporates both computer equipment and computer program systems (software). The integral relationship between hardware and software requirements is critical to the cost-effective application of computer technology in training systems development. Computer equipment capabilities are directly related to the level and efficiency of computer programming capabilities and thus have a major impact on life-cycle cost and supportability.

A new "megamini" computer technology is evolving which will have a major impact on the real time computational technology. The megamini computer adds a new dimension in real time computation by combining the powerful instruction set and performance capacity of the 32-bit computer with the low cost of 16-bit minicomputers. These computers typically feature high rate internal processing, including fast floating-point, which facilitates real time compiler level (high order language) programming.

The specific impact of the megamini computer on training simulators is the cost-effective application of FORTRAN language to the real time computer program requirements. This computer technology applications "breakthrough" will permit an improvement in life-cycle costs and the cost-effective utilization of training simulators. In particular, software supportability will be simplified with changes to the computer program system being simpler to accomplish and therefore less costly.

A preliminary Technical Memorandum, ASD/ENCT-75-2 "Considerations in High Order Language Compiler versus Assembler for Programming Real Time Training Simulators", has been prepared as part of an AFSC study to establish applicability, commonality and standardization of programming language(s) across all AFSC acquired systems. This study will identify information processing requirements and recommend programming language approaches to defense and weapon system applications including training simulators.

Associated with the increased speeds and total processing capacity of digital computers has been the application of digital processing technology across a wider spectrum of the simulator information processing requirements. For example, out-the-window visual and sensor information is being stored and processed with digital technology including large capacity random access magnetic storage devices, real time retrieval and processing computers and high-speed digital pipeline processors. The impact of these approaches is the distribution of several general purpose computers throughout one simulator system. Visual subsystems and sensor subsystems, e.g., radar landmass systems, can be developed as add-on subsystems contracted separately from the simulator. Certain digitally based visual systems have been developed and are competitively available commercially as a developed standard product, including the computer subsystem equipment and programs. Thus, computer equipment commonality and standardization may be achieved either within a weapon system simulator, or across weapon system simulators within subsystem application areas. These alternatives are being reviewed to assess the practicalities of acquisition and minimal development risk with the objectives of commonality and standardization.

Another consideration in computation technology is the advent and application of micro processors. Micro processors can be developed for very low costs as dedicated functional processors. These microelectronic digital processors can be designed to perform specific dedicated functions such as trignometric, transcendental, matrix manipulation, linear function interpolation, and other functions which have a low probability of variance over the life of the simulator. These "hardwired" processors may be designed and developed as more cost-effective approaches to the implementation of simulator computational requirements. Micro processors also offer the potential advantage of being standard electronic components if the functions implemented are properly identified and defined.

Computer program system (software) definition, acquisition and life-cycle support have been the subjects of high-level concern and attention across all AF activities. Project Pacer Flash was initiated in response to AFR 20-1 which established a requirement to assess methods of providing support for weapon systems software. Pacer Flash Final Report, Volume IV, Appendix C, addresses Aircrew Trainers and contains a recommended concept involving a combination of AFSC, AFLC, and using command activities to achieve software supportability in simulators. Following the Pacer Flash Study, a new Air Force Regulation, AFR 800-14, was written addressing acquisition management of computer resources. An ASD weapon systems software workshop was conducted at which the concepts and challenges associated with the acquisition of simulator software were discussed including the specific challenge of simulating on-board avionics computer software in the training environment. The relative merits of three approaches to simulating on-board operational flight programs were presented in a paper entitled: "Alternative Consideration for On-Board Computer Performance Simulation in Crew Trainers."

A program for continued technological development is outlined in Section D including a number of engineering developments required to exploit the products of advanced developments for the general improvement of Air Force computer resources.

7. Mathematical Modeling

The design process for simulators begins with derivation and development of mathematical models for all primary systems. The quality and fidelity of the simulator is directly related to the quality of the driving model. The crew inputs from, and system outputs to the simulator are controlled through the model as implemented in the computer system.

Mathematical models are mathematical representations of the real world system to be simulated. For the aircraft performance, the mathematical models are derived from approved design criteria, which consist of information defining weapon system performance and characteristics. This information is available in various documents and reports which are identified and compiled in a list called the approved criteria list. The total set of approved criteria defines the system including the environment to be simulated; e.g., electronic, tactical and other stimuli necessary to provide a realistic training situation. The flight performance data package is usually developed from wind tunnel testing although new flight testing techniques promise to provide improvement in stability and control data. Historically, models for simulators have been derived from the following data sources: aerodynamics - wind tunnel data; engine - ground testing with predictions for installation losses; control loading - ground tests of hardware and engineering design data; systems - engineering design data. Aerodynamic, engine, and control loading data derived i ese time honored methods have been historically in e. or producing simulators which do not precisely reproduce the flying qualities of the aircraft. Recent advances in flight test technology, specifically the parameter identification technique developed by NASA, Edwards AFB may provide a method of deriving flight related aerodynamic data. In addition, the Naval Air Test Center at Patuxent River Air Station has recently initiated a simulator test method which relies upon flight test techniques to verify the simulator.

Mathematical models must be derived in a manner to accurately depict the simulated system relative to training requirements. As the model requirements increase in complexity, the cost of the total system increases proportionately or in some cases, geometrically. As training requirements increase in terms of both high fidelity performance and more comprehensive environmental and instructional features, modeling requirements likewise increase in complexity with a net increase in system complexity and cost. Mathematical modeling techniques have not changed significantly from the time of early analog computer devices. With the advent of digital computing techniques, system performance tolerances were tightened since analog computation restrictions were eliminated. Tolerances were tightened as a direct function of computational technology availability, rather than as a function of simulator performance derived from training requirements. Considering this evolution of tolerances based on technology rather than training requirements, a restructuring and redefinition of completed parameters and associated tolerances offers a potential of improved training simulator realism together with a reduction in acquisition costs through identifying and eliminating over-simulation.

8. Adaptive Training

Presently the Air Force has no real capability to train students adaptively using an aircraft simulator. An F-4 training simulator at Luke AFB has what is referred to as an Adaptive Flight Training System (AFTS). The system has been well received by the user and has demonstrated the capability of providing effective training to the student pilots. However, the AFTS is not an adaptive system in the strict sense of the word. Though "adaptive" is used in the system title, there is evidence that the manufacturer/user definition of adaptive differs from the conventional one. Adaptive is usually understood to mean that the training task is modified automatically as a function of student performance. The modification is designed to enhance the student's learning and help him if he is having difficulty. The definition of adaptive that can be inferred from the AFTS at Luke AFB is limited to providing an automatic scoring feature when performing a ground controlled approach (GCA). The AFTS does provide training of the GCA but it is not an adaptive trainer in the sense of optimizing future training events on the basis of these scores.

For a training system to be adaptive, the computational system must, as mentioned above, modify the task being trained to enhance learning. This implies the solution of two critical problems in developing the adaptive trainer. First, for every procedure or maneuver that is to be trained, a scoring algorithm must be developed. This entails the gathering, weighting, combining and mathematical operation on predetermined system output variables such that an indication of student performance can be obtained. The resultant score must permit the objective ordering of task performance on the maneuver in question. Secondly, having determined the maneuver score, it is necessary to determine and construct the adaptive logic that will allow task modification to meet student skill level on a given trial. If a maneuver is to be trained in an adaptive manner, many "micro" decisions must be made by the user. For instance, if a loop is to be trained, the user may want to begin the sequence by damping some of the dynamic characteristics of the aircraft. Then, as the student improves, the amount of damping is lessened until the real aircraft is being flown. An alternative to this approach would be to dissect the maneuver into smaller sub-maneuver segments and have the student train to some criteria on these smaller segments. Whatever method is employed, it is imperative that the user participate actively in the development of this logic for each task (maneuver) that is to be trained. From the brief discussion above, it is apparent that, for each maneuver to be trained, a separate scoring algorithm must be obtained and an adaptive logic developed.

Should a user contemplate the use of an adaptive device, there are several important factors that must be considered:

(1) The amount of adaptive training required directly and significantly impacts the amount of computer core and the size of the associated software package. For example, ideal maneuver profiles must be stored as well

as student performance history on each maneuver. This performance history is in the form of scores obtained from the scoring algorithm which is also part of the computational system.

(2) The using command must play an active role in the development of the adaptive logic. This requires the use of extensive manpower resources and in most cases will require the establishment of an organic unit with expertise in learning theory and advanced training techniques. The alternative is contractual arrangements on a continuing basis.

(3) The particular tasks or maneuvers that are to be trained using adaptive techniques must be selected with extreme care. The literature is fairly conclusive that tasks, which can be easily broken into discrete steps, can be trained in an adaptive manner. This is not the case when dealing with dynamic control tasks which may constitute a significant portion of the total training program. Whether or not it is possible to break up some of the dynamic control tasks (maneuvers) into smaller sub-tasks, has not been demonstrated conclusively.

In summary, the computer aided instruction or adaptive training area, particularly when dealing with dynamic control tasks, is considered to be an extension of our present state-of-the-art. There are, therefore, correspondingly high risks in terms of dollar and manpower resources required to develop the logic and algorithms needed to effectively apply adaptive training features in sophisticated simulators. For the present, effort should be limited to those tasks that are easily defined and quantified; i.e., ILS and TACAN approaches. Prior to making commitments to full-scale development of an AFTS for integration with a mission simulator, a prototype AFTS should be funded.

D. DEVELOPMENT PROGRAMS

1. Development Responsibilities

The Air Force Human Resources Laboratory (AFHRL) as assigned by AFSC Regulation 23-1 is responsible for the conduct of Exploratory Development under PE 62703F, "Human Resources" and Advanced Development under PE 63102F, "Innovations in Training and Education." The Exploratory Development projects under PE 62703F which are directed towards the development of training simulation technology are: Project 6114, "Simulation Techniques for Air Force Training", Project 1710, "Training for Advanced Air Force Systems", and Project 1123, "USAF Flying Training Development." Project 6114 is for the development of training simulation techniques and devices and Projects 1710 and 1123 are for the development of the human factors aspects of training simulation. The advanced development projects under PE 63102F directed towards the development of training simulation technology are Project 1192, "Advanced Simulation in Undergraduate Pilot Training" and Project 1958, "Training Simulation Technology Integration." Project 1192 is being conducted in two phases. The first phase, completed in January 1975 was for the development of an advanced state-of-the-art training simulation research tool, the ASUPT system. The second phase, now underway, is the utilization of this research tool in an experimental program in undergraduate pilot training. Project 1958 is for the design, development, and fabrication of integrated simulation systems or major subsystems for test and demonstration of their performance capabilities.

Three other Laboratory organizations, the Aerospace Medical Research Laboratory (Aerospace Medical Division) and the Avionics Laboratory and Flight Dynamics Laboratory, now a part of the newly formed Wright Aeronautical Laboratory, are involved in simulation. Although training simulation is a very specialized field of technology with its own set of problems, methods, data bases, and criteria it can profit from advances made in engineering simulation. There are both commonalities and dissimilarities in simulators designed for different purposes, and these must be carefully considered when making decisions about the applicability of techniques from one area to another. The commonality is the "equipment"; the differences are in how the equipment or tools are used and for what purpose.

The basic difference in mission responsibilities between AFHRL and the other Laboratories involved in simulation is that of developer versus user. AFHRL has the responsibility for developing training simulation technology, whereas, the other Laboratories are users of simulation for medical or engineering analysis or design. Recognition of the fact that the field of training simulation can profit from the "spin-off" of simulation efforts of the other Laboratories led to AFHRL, in January 1975, being assigned the responsibility of Focal Point Laboratory for training simulation technology. This responsibility includes: (1) maintaining an awareness of all significant R&D being conducted by the other AF Laboratories, other DoD organizations, NASA, and Industry's IR&D; (2) making recommendations concerning work assignments, the elimination of redundancy, changes in emphasis, and required resources; and (3) preparation of an overview covering all Air Force training and training related simulation technology on an annual basis.

The Deputy for Development Planning, Aeronautical Systems Division, is responsible for Project A167, "Aircraft Simulator Commonality Study", which is part of PE 63101F, "Preliminary Design and Development." This project is directed toward study of selected areas of possible simulator component commonality.

The Simulator SPO, with engineering assistance from the Simulators and Human Factors Division, Deputy for Engineering, is responsible for engineering development projects to adapt existing technology to training simulator applications. Current and planned development programs are PE 63719F, Project 688E, "Simulator for Air-to-Air Combat"; PE 64708F, "Other Operational Equipment"; Project 1183, "Digital Radar Land Mass"; PE 64227F, "Flight Simulator Development", which is wholly dedicated to simulator engineering development; and the B-52 Instructional System Sensor RDT&E. Management, engineering and financial responsibility has been requested for specific simulator computer systems projects proposed under PE 64740F, "Applications for Information Processing Technology."

2. Development Funding

The exploratory development budget for training simulation technology development within the Air Force has steadily declined since 1960 to a zero funding level in FY 75. The advanced development budget has been at a reasonable level since 1971; however, it has been solely devoted to one project, the ASUPT system development.

Project 1958, "Training Simulation Technology Integration", was initiated in FY 72, but was zero funded for three years until near the end of FY 75. This situation of limited resources available to the Laboratory responsible for simulation technology development has resulted in (1) the technology development programs falling far behind the technology requirements for simulator acquisition programs, (2) the conduct of exploratory and advanced development on hardware development programs, (e.g., F-4E #18), and (3) the conduct of advanced development efforts by other organizations with available resources.

The funding situation for exploratory and advanced development in FY 76 is improving; however, the advanced development budget is still at about one-half the required level. Because of the past funding situation most of the exploratory and advanced development programs described in this section are new starts. Those that are continuing efforts were funded by Laboratory Directors funding or advanced development funding released near the end of FY 75. Since the advanced and exploratory development efforts are lagging far behind, many are catch-up efforts which require initial funding levels greater than those required for a continuing program that has kept pace with the technology needs. Also, the milestone dates for the described programs are based on the available funding and not technology need dates for the acquisition programs. Funding in FY 76, FY 7T, and FY 77 is ten to thirty percent below requested levels. Because of the lower than required funding levels it is not possible to start some development programs and others are artificially stretched to match the approved funding.

Reduction in engineering development funding in PE 64227F has resulted in schedule slippages and will delay obtaining some capabilities on production simulators.

3. Development Program Descriptions

Development Programs are planned and in process in two allied areas, training simulation technology development and supporting research. The former is focused on the development of improved methods of simulation while the latter is aimed at improving our fundamental understanding of the training process as influenced by simulator capability and instructional strategies.

Table II-2A summarizes planned development tasks and projects by technical area and includes 6.2 exploratory development, 6.3 advanced development, 6.4 engineering development, and system RDT&E. Funding levels required to support the projects shown in Table II-2A are contained in Annex A by corresponding technical areas. Table II-2B summarizes the schedules for each planned task or project. Table II-2C relates planned development projects to simulator requirements and assesses the relative "criticality" of the specific development in meeting the stated or anticipated full requirement. The assessment is based on stated or expected requirements and not on currently proposed procurement alternatives. A brief explanation of each of the tasks and projects follows:

a. Visual

(1) CIG Image Improvement

Through experience gained during the acceptance testing and early utilization of the ASUPT Computer Image Generation (CIG) System the lack of velocity and altitude cues, especially near the ground, became apparent. This shortcoming of current CIG systems is the result of a lack of texture and contour in the ground plane imagery. This exploratory effort will develop and evaluate in a dynamic mode, algorithms for generating ground plane texturing and contouring.

(2) High Brightness and Resolution Color Projector

Mosaicked, in-line, on-axis virtual image displays have been successfully developed for both the ASUPT and SAAC systems. These displays however, are monochrome systems due to the low transmission efficiency of the display optics which necessitates a high brightness image input source, a CRT in this case. Color CRTs of the required brightness are beyond the state-of-the-art. This exploratory effort will develop conceptual designs for a high brightness and high resolution color projector to be used as an image input to the ASUPT and SAAC type displays to provide color.

(3) Wide-Angle Multi-View Display

The ASUPT and SAAC type displays are wide-angle displays; however, they provide a correct visual scene for only one viewer. This effort will study and develop new techniques for providing wide-angle multi-view display capability for future multi-crew visual requirements.

TABLE II-2A

SUMMARY OF PLANNED SIMULATOR TECHNOLOGY DEVELOPMENT PROGRAM

TECHNICAL AREA/TITLE	B.P.	P.E.	PROJECT	TASK	OPR
a. VISUAL					
1. CIG Image Improvement	6.2	62703F	6114	05	AFHRL/AS
2. High Brightness & Resolution Color Projector	6.2	62703F	6114	05	AFHRL/AS
3. Wide Angle Multi-View Display	6.2	62703F	6114	05	AFHRL/AS
4. Holographic Infinity Display Lens Analog	6.1	61101F	ILIR	--	AFHRL/AS
5. Wide Angle High Res Monochrome Visual	6.3	63102F	1958	01	AFHRL/AS
6. Wide Angle High Res Color Visual	6.3	63102F	1958	01	AFHRL/AS
7. Wide Angle Multi-View Display System	6.3	63102F	1958	01	AFHRL/AS
8. Advanced Visual System	6.3	63102F	1958	01	AFHRL/AS
9. Aerial Refueling					
(a) B-52 ARPTT	6.4	64227F	2201	--	ASD/SMS
(b) KC-135 BOPTT	6.4	64227F	2201	--	ASD/SMS
10. Air-to-Ground Visual System	6.4	64227F	2235	--	ASD/SMS
11. Multi-View Visual, Wide Field of View	6.4	64227F	2322	--	ASD/SMS
12. Tactical Air-to-Ground Simulation					
(a) Advanced Developments	6.3	63XXX	XXXX	--	AFHRL/AS
(b) Engineering Developments	6.4	64227F	22XX	--	ASD/SMS
b. SENSOR					
1. Sensor Data Base Characterization	6.2	62703F	6114	14	AFHRL/AS
2. Sensor Data Base Compression Techniques	6.2	62703F	6114	14	AFHRL/AS

TABLE II-2A

SUMMARY OF PLANNED SIMULATOR TECHNOLOGY DEVELOPMENT PROGRAM (CONTINUED)

TECHNICAL AREA/TITLE	B.P.	P.E.	PROJECT	TASK	OPR
3. High Density Cultural Generation	6.2	62703F	6114	14	AFHRL/AS
4. DRLMS Data Base Adaptation	6.3	63102F	1958	03	AFHRL/AS
5. Sensor Demonstration System Design	6.3	63102F	1958	03	AFHRL/AS
6. Sensor Demonstration System Development	6.3	63102F	1958	03	AFHRL/AS
7. Alternate Sensor Approaches	6.3	63102F	1958	03	AFHRL/AS
8. B-52 Electro-Optical Viewing System	RDT&E	11113F	2269	--	ASD/SMS
c. MOTION AND FORCE					
1. Motion Sensory Mechanism Modeling	6.2	62703F	6114	19	AFHRL/AS
2. Motion Drive Algorithm Development	6.2	62703F	6114	19	AFHRL/AS
3. Control Loading System Development	6.2	62703F	6114	19	AFHRL/AS
4. G-Seat Component Development	6.2	62703F	6114	19	AFHRL/AS
5. Advanced Low Cost G-Seat	6.3	63102F	1958	02	AFHRL/AS
6. High-G Augmentation Devices	6.3	63102F	1958	02	AFHRL/AS
7. ASUPT Motion System Drive Mod.	6.3	63102F	1958	02	AFHRL/AS
d. ADVANCED INSTRUCTIONAL FEATURES					
1. Performance Measurement Pilot Modeling	6.2	62703F	6114	20	AFHRL/AS
2. Advanced Instructional Hardware Devices	6.2	62703F	6114	20	AFHRL/AS
3. Simulator Instructional Features Design Guide	6.2	62703F	1710	03	AFHRL/AS

TABLE II-2A

SUMMARY OF PLANNED SIMULATOR TECHNOLOGY DEVELOPMENT PROGRAM (CONTINUED)

TECHNICAL AREA/TITLE	B.P.	P.E.	PROJECT	TASK	OPR
4. Simulator Instructional Features Development	6.4	64227F	2324	--	ASD/SMS
e. MODELING AND COMPUTATION					
1. Simulator Tolerances	6.2	62703F	6114	07	AFHRL/AS
2. Simulator Testing Tolerances	6.2	62703F	6114	07	AFHRL/AS
3. Simulator Higher Order Languages	6.2	62703F	6114	07	AFHRL/AS
4. Advanced Computational Techniques	6.2	62703F	6114	07	AFHRL/AS
5. Central vs. Distributed Computers	6.4	64740F	--	--	ASD/SMS/ENCT
6. Simulation of On-board Avionics Software	6.4	64740F	--	--	ASD/SMS/ENCT
7. Hardware vs. Software Implementation of Specific Functions	6.4	64740F	--	--	ASD/SMS/ENCT
8. Standardize Software Development Task Definitions	6.4	64740F	--	--	ASD/SMS/ENCT
9. ASD Regulation for Simulation Computer System Application	6.4	64740F	--	--	ASD/SMS/ENCT
10. High Order Language Applicability	6.4	64740F	--	--	ASD/SMS/ENCT
11. Computer Programming Techniques	6.4	64740F	--	--	ASD/SMS/ENCT
12. Computer Selection Model	6.4	64740F	--	--	ASD/SMS/ENCT
f. SIMULATION REQUIREMENTS VALIDATION AND SPECIFICATION					
1. Behavioral Data in Design Guide	6.2	62703F	1710	03	AFHRL/AS

TABLE II-2A

SUMMARY OF PLANNED SIMULATOR TECHNOLOGY DEVELOPMENT PROGRAM (CONTINUED)

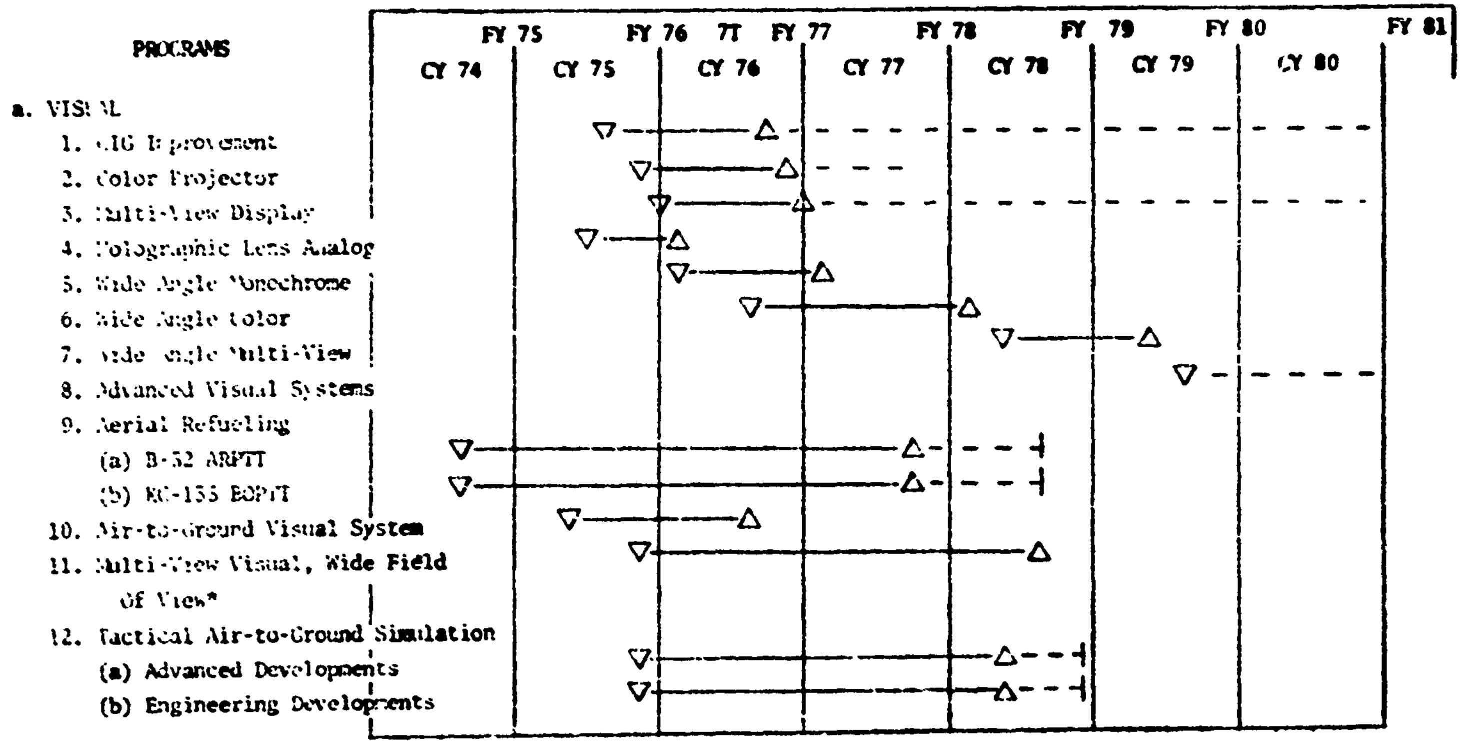
SUMMARY OF PLANNED SIMULATOR TECHNOLOGY DEVELOPMENT PROGRAM (CONTINUED)

TECHNICAL AREA/TITLE	R.P.	P.E.	PROJECT	TASK	OPR
2. Aircraft Simulator Commonality Study	6.3	63101F	A167	--	ASD/XR
g. SIMULATION APPLICATION/EVALUATION					
1. F-106 MA-1A Attack Radar Trainer	6.2	62703F	1710	03	AFHRL/AS
2. Aerial Gunnery Part Task Trainer	6.2	62703F	1710	03	AFHRL/AS
3. Advanced Systems Exploitation	6.3	63102F	1192	--	AFHRL/FT
(a) ASUPT	6.2	62703F	1123	--	AFHRL/FT
(b) SAAC	6.2	62703F	1123	--	AFHRL/FT
(c) F-4E#18	*			--	AFHRL/FT
(d) DRLMS	6.4	64708F	1183	--	ASD/SMS

* Procured as a part of F-4 production program.

TABLE II-2B

DEVELOPMENT PROGRAM SCHEDULE



* ASSUMES FUNDS PROVIDED IN FY 76.

TABLE II-2B

DEVELOPMENT PROGRAM SCHEDULE (CONTINUED)

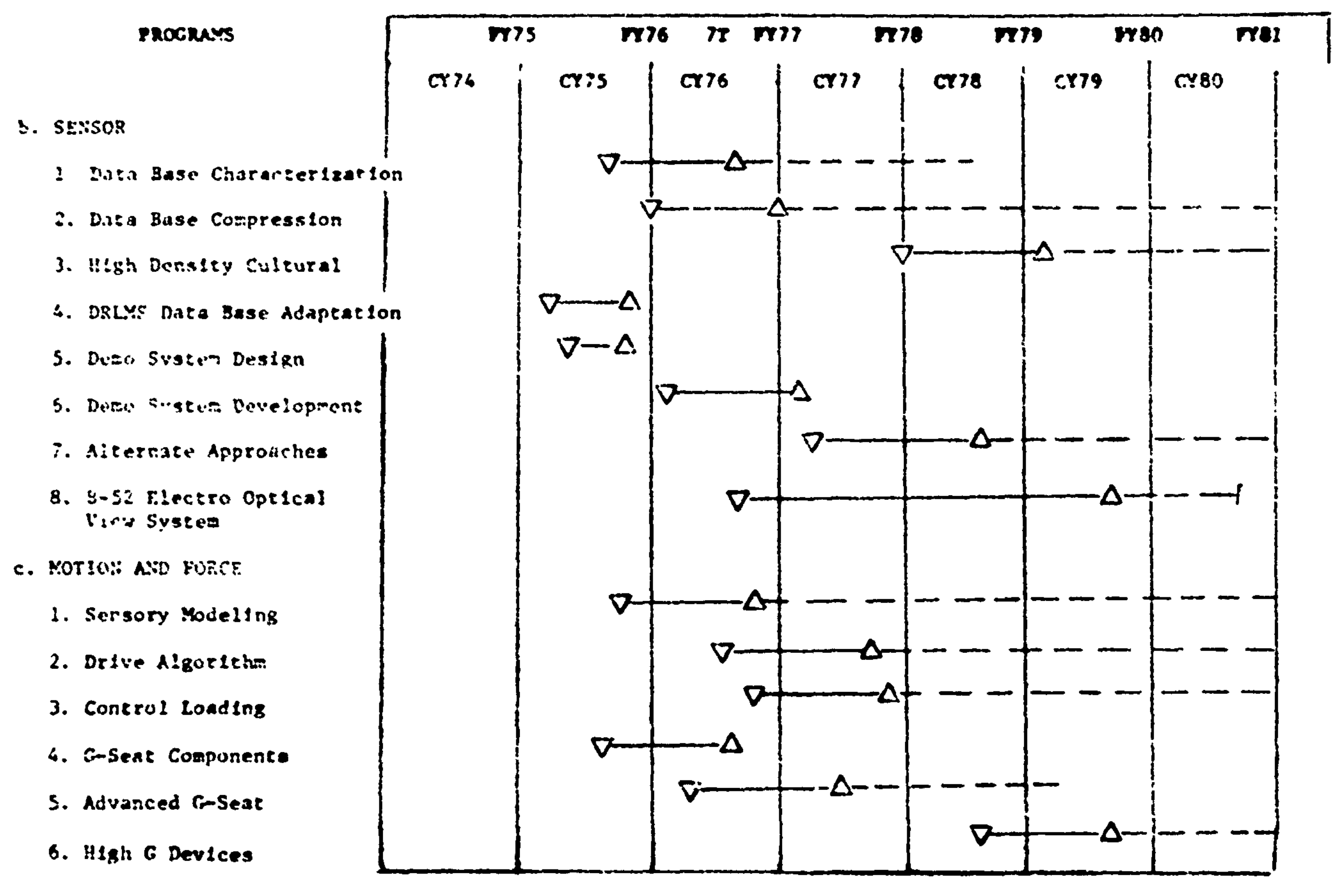


TABLE II-2B

DEVELOPMENT PROGRAM SCHEDULE (CONTINUED)

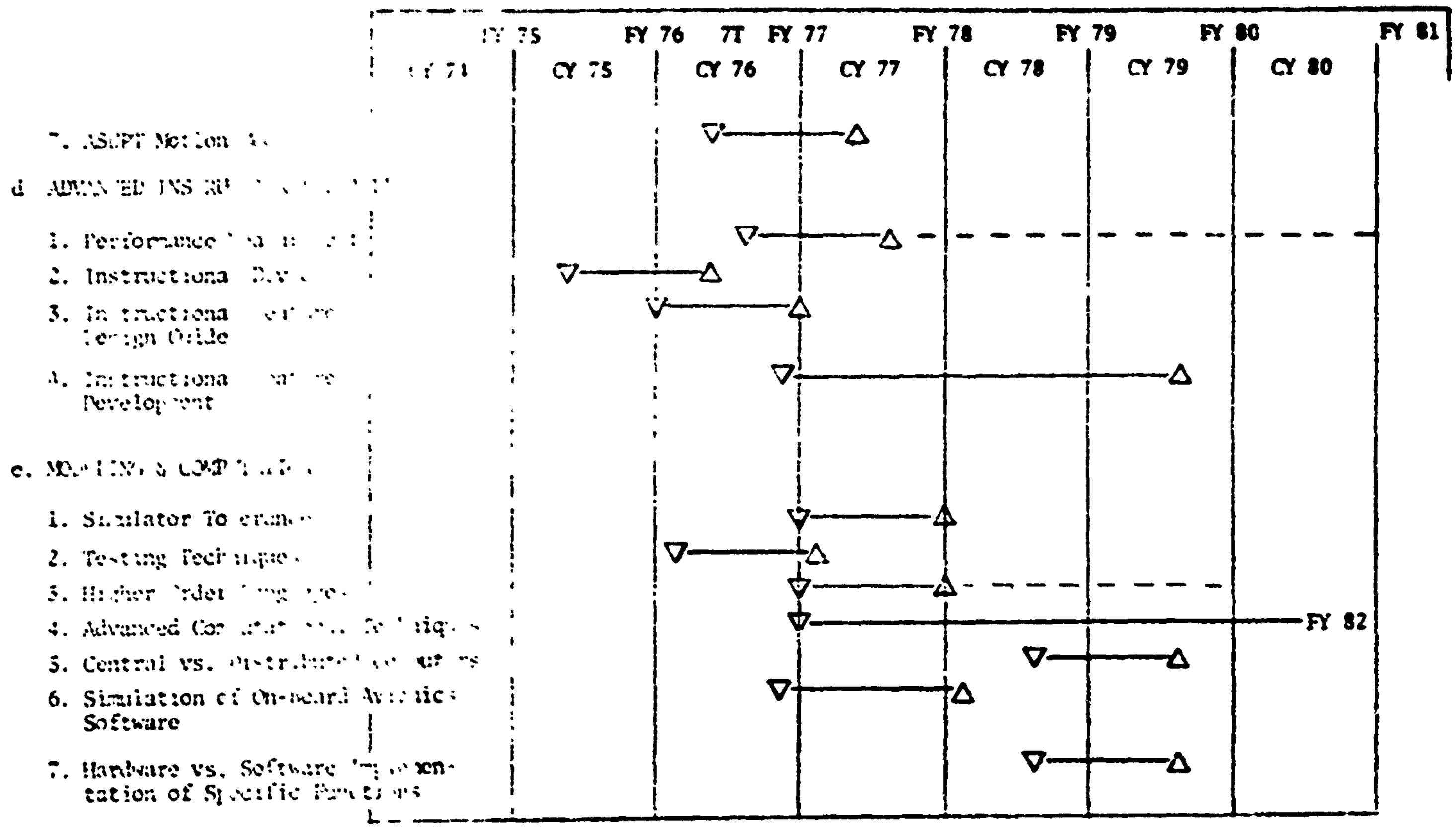


TABLE II-2B

DEVELOPMENT PROGRAM SCHEDULE (CONTINUED)

PROGRAM

8. Stand ... Development Task Definition
9. ASD R...ulation for Simulation Computer System Application
10. High Order Language Applicability
11. Computer Programming Techniques
12. Computer Selection Model

f. SIMULATOR RE...T VALIDATION AND SPECIFICATION
1. Behavioral Design Guide
2. ACFT Simulator Commonality Study

g. SIMULATION APPLICATION/ EVALUATION
1. MA-1 Trainer
2. Aerial Gunnery Trainer
3. Advanced Systems Exploitation

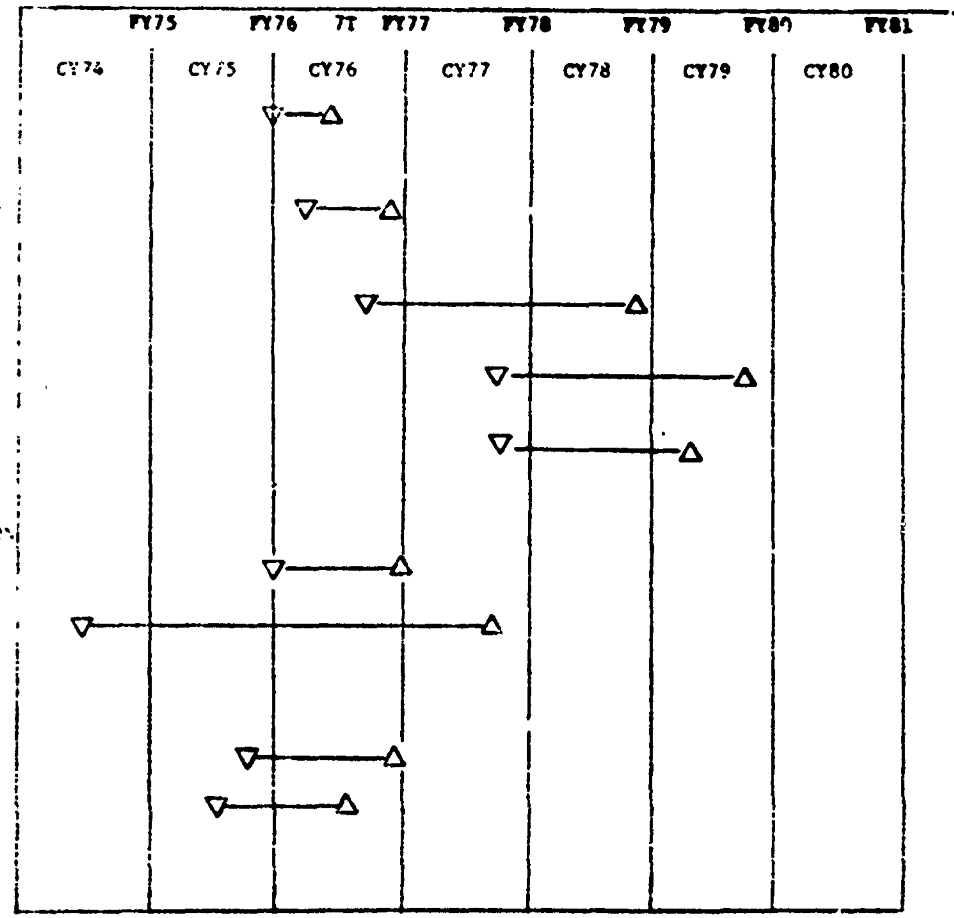


TABLE II-2B

DEVELOPMENT PROGRAM SCHEDULE (CONTINUED)

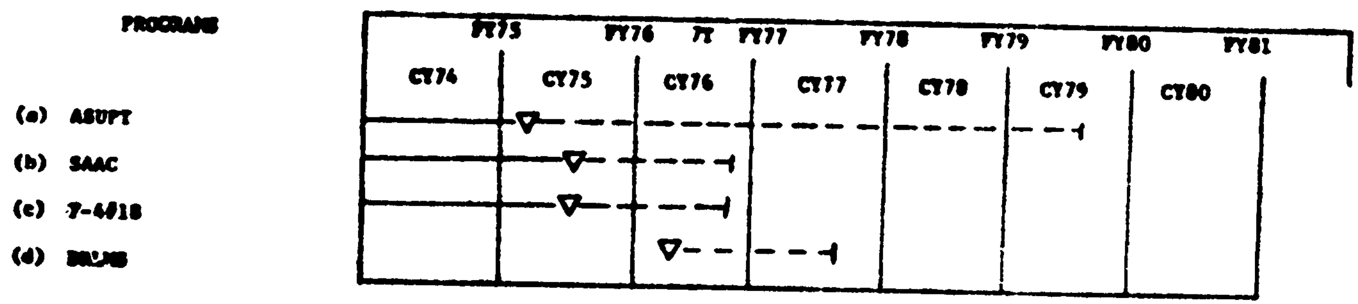


TABLE II-2c

CRITICALITY OF PLANNED DEVELOPMENT IN MEETING SIMULATION REQUIREMENTS

(L - LOW, M - MODERATE, H - HIGH, BLANK - NOT APPLICABLE)

REQUIREMENT/DEVELOPMENT	a.1.(1)	a.2.	a.3.	a.4.	a.5.	a.6.	a.7.	a.8.	a.9.	a.10.	a.11.	a.12.	b.1.	b.2.	b.3.	b.4.	b.5.	b.6.	b.7.	b.8.
A-10 F.M.S.	M	H		M	M	M		L	L	H		H								
F-16 F.M.S.	M	H		M	M	M		L	L	H		H								
F-15 Visual Add. *	M	H		M	M	M		L	L	H		H								
F-4D/E WSTS	M	H		M	M	M		L	L	H		H								
F-4 Wild Weasel *	M	H		M	M	M		L	L	H		H								
A-7D Visual Add.	M	H		M	M	M		L	L	H		L								
B-52 I.S.			M				M		M		M		M	M	M	H	M	M	M	M
B-1 F.M.S. *			M				M		M		M		M	M	M	H	M	M	M	M
CH-3/HH-53 Visual Add.	M		M				M		L		M									
C-130 M.S.		L	M				M				M									
AMST M.S. *		L	M				M				M									
KC-135 I.S.									M		M									
ATCA M.S. *									H		M									

* Requirements not yet formal ROC.

(1) References a.1-a.12, b.1-b.8, etc., shown in this Table correspond to those programs shown in Tables II-2A, II-2B and II-2C.

TABLE II-2c

CRITICALITY OF PLANNED DEVELOPMENT IN MEETING SIMULATION REQUIREMENTS (CONTINUED)
(L - LOW, M - MODERATE, H - HIGH, BLANK - NOT APPLICABLE)

REQUIREMENT/DEVELOPMENT	a.1.	a.2.	a.3.	a.4.	a.5.	a.6.	a.7.	a.8.	a.9.	a.10.	a.11.	a.12.	b.1.	b.2.	b.3.	b.4.	b.5.	b.6.	b.7.	b.8.
C-9 M.S.																				
UPT-FFT *																				
KC-135 Visual Add. *	L																			
RW RECCE Sim.																				
EF-111A T.J.S. PTT *																				

* Requirements not yet stated in formal ROC.

TABLE II-2c

CRITICALITY OF PLANNED DEVELOPMENT IN MEETING SIMULATION REQUIREMENTS (CONTINUED)

(L - LOW, M - MODERATE, H - HIGH, BLANK - NOT APPLICABLE)

REQUIREMENT/DEVELOPMENT	c.1.	c.2.	c.3.	c.4.	c.5.	c.6.	c.7.	d.1.	d.2.	d.3.	d.4.	e.1.	e.2.	e.3.-e.12	f.1.	f.2.	g.1.	g.2.	g.3.(a)	g.3.(b)	g.3.(c)	g.4.(a)
A-10 F.M.S.	M	M	M	M	M	M	L	M	M	L	L	L	M	L	L	L	L	L	H	L	M	
F-16 F.M.S.	M	M	M	M	M	M	L	M	M	L	L	L	M	L	L	L	L	L	H	H	M	
F-15 Visual Add.	M	M	M	M	M	M	L	M	M	L	L	L	M	L	L	L	L	L	H	H	M	M
F-4DE WSTS	M	M	M	M	M	M	L	M	M	L	L	L	M	L	L	L	L	L	H	H	M	M
F-4 Wild Weasel	M	M	M	M	M	M	L	M	M	L	L	L	M	L	L	L	L	L	H	H	M	M
A-7D Visual Add.	M	M					L					L		L	L	L	L	L	H		M	
B-52 I.S.	M	M					L	L	L	L	L	L	L	L	L	L	L	L	H			M
B-1 F.M.S.	M	M					L	L	L	L	L	L	L	L	L	L	L	L	H			M
CH-3/HH-53 Visual Add	M	M					L	M	M	L	L	L	L	L	L	L	L	L	H			
C-130 M.S.	M	M					L	M	M	L	L	L	L	L	L	L	L	L	H			M
AMST M.S.	M	M					L	M	M	L	L	L	L	L	L	L	L	L	H			L
KC-135 I.S.	M	M					L	L	L	L	L	L	L	L	L	L	L	L	H			L
ATCA M.S.	M	M					L	L	L	L	L	L	L	L	L	L	L	L	H			L
C-9 M.S.	M	M					L	L	L	L	L	L	L	L	L	L	L	L	H			
UPT-FFT	M	M					L			L	L	L	L	L	L	L	L	L	H			

TABLE II-2c

CRITICALITY OF PLANNED DEVELOPMENT IN MEETING SIMULATION REQUIREMENTS (CONTINUED)

(L - LOW, M - MODERATE, H - HIGH, BLANK - NOT APPLICABLE)

REQUIREMENT/DEVELOPMENT	c.1.	c.2.	c.3.	c.4.	c.5.	c.6.	c.7.	d.1.	d.2.	d.3.	d.4.	e.1.	e.2.	e.3.-e.12	f.1.	f.2.	g.1.	g.2.	g.3.(a)	g.3.(b)	g.3.(c)	g.4.([illegible])
KC-135 Visual Add.												L	L	L	L	L	L	L	H			
EW RECCE Sim.										L	L	L		L	L	L	L	L	H			
EF 111A T.J.S. PTT										L	L	L		L	L	L	L	L	H			

(4) Holographic Infinity Display Lens Analog

This effort will investigate and determine the feasibility of fabricating large holographic spherical beam splitter lens analogs for use in in-line, on-axis infinity optics (pancake window) systems. A 17-inch feasibility model will be developed and used with corresponding size optical elements in a pancake window for test and evaluation.

(5) Wide-Angle High Resolution Monochrome Visual

This effort will be a four phased program to develop a fully integrated high resolution, wide-angle monochrome visual system comprised of a three channel holographic pancake window display, a terrain board, a wide-angle probe, a high resolution TV camera, and image splitting and processing equipment. The emphasis in this effort will be placed on the display system.

(6) Wide-Angle High Resolution Color Visual

The wide-angle high resolution color visual system effort will be similar to the monochrome effort except that a color capability will be developed and demonstrated. The key developmental components in this effort will be trichroic holographic pancake window displays and a high brightness, high resolution color projector for the image input.

(7) Wide-Angle Multi-View Display System

This effort will develop and fabricate an optical display system which will provide a wide field-of-view with an exit pupil large enough to provide the same visual scene to multiple crew members for the wider body aircraft.

(8) Advanced Visual System

This effort will develop and demonstrate new complete visual systems based on the results of the 6.2 exploratory development program.

(9) Aerial Refueling

(a) The B-52 Aerial Refueling Part Task Trainer (ARPTT) prototype will be used to test the feasibility of substituting ground training for airborne training of aerial refueling skills. The ARPTT will be a contractual effort incorporating a virtual image display, a camera-model image generation system, cockpit equipped only with equipment and controls essential for aerial refueling and a motion system adequate for simulation of aerial refueling parameters.

(b) The KC-135 Boom Operator Part Task Trainer (BOPTT) prototype is an in-house effort to incorporate a virtual optical image display, having the capability of providing true 3-dimensional changes to boom perspective, a fixed base boom operator station (made from an actual KC-135) configured with the equipment/controls essential for aerial refueling and an image generation system. Effort will concentrate on the B-52 receiver with possible future expansion to other receivers.

(10) Air-to-Ground Visual System

This project will analyze and demonstrate the technical feasibility of air-to-ground (A/G) weapon delivery simulation in order to lower the performance and cost risk of procuring aircrew simulators which require A/G simulation capabilities. Three distinct approaches to visual simulation will be investigated as shown below:

(a) SAAC/F-4E #18: The F-4E #18 simulator will be modified to provide a ground target Area of Interest (AOI) from the F-4E #18 terrain model board to the Cathode Ray Tube (CRT) infinity visual display of the SAAC.

(b) LAMARS: A ground AOI from the AFFDL Redifon terrain model board will be input to the Large Amplitude Multi-Mode Aerospace Research Simulator (LAMARS) dome display.

(c) ASUPT: A ground AOI will be programmed into the Advanced Simulator for Undergraduate Pilot Training (ASUPT) digital data base. This will be used for computer image generation to be displayed by the ASUPT CRT infinity visual system.

(11) Multi-View Visual, Wide Field of View

This will be a new effort to adapt existing technology to meet near term simulation requirements for large, multi-crew aricraft. Requirements include wide field of view, simultaneous viewing by more than one crew member in a large cockpit, large gaming area, and color imagery. Phase I will be an in-house effort to test and evaluate off-the-shelf and state-of-the-art components in various synthesized system configurations. Phase II will involve design, development, fabrication, demonstration, and evaluation of integrated system hardware.

(12) Tactical Air-to-Ground Simulator

This is a proposed joint AFHRL and ASD program to improve simulation for air-to-ground training. It will not be limited to visual developments. The program will consist of AFHRL advanced development efforts and ASD engineering development efforts. The three phase approach is to (1) conduct a definition study, (2) purchase a baseline simulation capability, and initial advanced developments, and (3) conduct a continuing period of new advanced and engineering developments, test, and evaluation as new technology is needed and becomes available. This effort will be concurrent with production air-to-ground visual systems for the A-10, F-16, F-4E, and A-7 simulators which may result from the air-to-ground visual system project. (Paragraph (10), above).

b. Sensor

(1) Sensor Data Base Characterization

Infrared (IR) sensors provide imagery corresponding to the temperature of the target imagery rather than reflected light as in TV systems or reflectivity as in radar systems. This imagery changes as a function of the time of day and seasons of the year. This effort is using the Avionics Laboratory tower facility to characterize and develop IR data bases for the four seasons of the year.

(2) Sensor Data Base Compression Techniques

The simulation of large gaming areas at relatively high resolution for sensor simulation results in enormously large data bases. This effort is to investigate the use of transform techniques for storage and manipulation of the sensor data bases thereby reducing the required storage and associated real time processing.

(3) High Density Cultural Generation

The simulation of high density cultural areas to a high degree of fidelity is considerably beyond the near future state-of-the-art of sensor simulation. This effort will explore data compression and processing techniques for simulating sensor scenarios of regularly shaped high detail cultural areas.

(4) DRLMS Data Base Adaption

This effort is a continuation of previous efforts to assess the feasibility of adapting the Project 1183 DRLMS data base for use in infrared (IR) simulation for terrain avoidance flying. Also, the size, complexity, and cost of a real time IR system for simulating this area will be estimated. In addition, a hardware program using an existing state-of-the-art radar system, the DRLMS data base, and scan converters is being conducted in a preliminary determination of the applicability of digital radar landmass simulation technology to the simulation of Electrooptical Viewing System (FVS) for the B-52 and B-1 mission simulators. The scan converters convert a C-scan radar presentation into a raster scan format. The effort is evaluating the adequacy of the radar system update rate, the distortions involved in the conversions, and determining the necessity of image improvement features such as edge smoothing.

(5) Sensor Demonstration System Design

This effort is a continuation of a competitive design study involving three contractors who are developing designs for a limited real time/flexible non-real time sensor simulation demonstration system. This effort which began near the end of FY 75 is directed towards the IR & LLLTV simulation areas. From these three competitive designs, the best design will be selected for implementation.

(6) Sensor Demonstration System Development

This effort will develop a limited real time, flexible nonreal time system for demonstrating and evaluating the selected computer image generation approaches to low light level TV (LLLTV) and IR sensor simulation. Highly detailed dynamic scenarios will be demonstrated through the video recording of nonreal time generated scenes and playback in real time. This effort will develop the hardware system and demonstrate and evaluate the selected approach.

(7) Alternate Sensor Approaches

This effort will use the sensor demonstration system described in (3) above and implement alternate CIG approaches to LLLTV and IR simulation for demonstration and evaluation. The evaluations will assess the quality of the resulting imagery and the size, complexity, and cost of a real time implementation of the particular approach.

(8) B-52 Electro-Optical Viewing System (EVS)

The B-52G/H Instructional System EVS development program will result in a real time digital, stand-alone, FLIR/LLLTV prototype, which will be developed and tested independently of the mission simulators. The system development will place the highest priority on simulation of EVS performance during low level penetration, and in particular, during terrain avoidance. It is anticipated that development and evaluation of the B-52 EVS simulation algorithms will be facilitated by the AFHRL Sensor Demonstration System. The system will utilize transformed DMAAC* digital data. Development of the transformation programs for the DMAAC to B-52 EVS data bases will be accomplished under the EVS development program.

c. Motion and Force

(1) Motion Sensory Mechanism Modeling

Although motion and force simulation systems have been specified for nearly every recent simulator procurement, there is little information concerning the training effectiveness of existing systems or the degree of simulation required for future systems. Motion system designs are typically based on aircraft performance with little attention given to the human to which the motion systems are intended to impart cues. This effort will concentrate on the human and how he perceives motion through his various sensing mechanisms (vestibular, somatic, visual, etc.) in order to determine what mechanisms are most important for stimulation and new and unique means of stimulation to produce the sensations of motion and force as experienced in flight.

(2) Motion Drive Algorithms

Motion platform hardware systems have progressed to a high degree of sophistication; however, drive algorithms for obtaining optimum performance have not kept pace. This effort will utilize the results of the motion sensory mechanism modeling effort in developing new motion platform drive algorithms which are intended to provide improved motion and derive the maximum performance from a given hardware system.

* Defense Mapping Agency Aerospace Center

(3) Control Loading System Development

Flight control loading systems are the pilots primary interface with the simulated aircraft. Deficiencies in the current systems unnecessarily extend simulator testing time and require changes to the flight model to overcome these deficiencies. This effort will investigate and develop new hardware control loading systems to improve their near neutral, small control movement force and control dynamics.

(4) G-Seat Component Development

This effort will improve g-seat components such as the individual seat air cells and pneumatic control valves. Closed loop drive methods will also be developed to improve seat response, reliability, and maintainability.

(5) Advanced Low Cost G-Seat

This effort will develop an advanced low cost g-seat embodying improvements in hardware actuators and software drive techniques. This effort is to result in a simplified g-seat which will have improved seat response, be easier to maintain, and cheaper to produce. Also, this effort will develop g-seats specifically tailored to new seat configurations (30° tilt) such as is in the F-16 aircraft.

(6) High G Augmentation Devices

This effort will develop new techniques and hardware devices such as arm, thigh, and head loading devices to augment motion systems for simulating the extremely high sustained "g" flight environment. These devices are to be designed as augmentation devices to be used with state-of-the-art motion platform hardware.

(7) ASUPT Motion System Drive Modification

The ASUPT motion system drive modification effort will involve the use of high speed minicomputer which will be integrated with the existing ASUPT computational system. The modification will allow the ASUPT motion software to execute at a faster iteration rate and allow the exploitation of new motion drive techniques such as nonlinear washout schemes and feedback hardware/software computations. It is anticipated that the increased computation rate of the motion software will eliminate motion lag/cue correlation problems which now exist in simulators in some flight regimes.

d. Advanced Instructional Features

(1) Performance Measurement Through Pilot Modeling

This effort will develop and adapt pilot modeling techniques as a means of objective pilot performance measurement. Both contemporary and advanced modeling methods will be considered, and those which are optimal for measurement applications and which will most accurately represent current behavioral theories will be explored. Resulting measurement techniques will be applied in basic simulation technology development studies and in the advanced instructional portions of flight simulators.

(2) Advanced Instructional Hardware Devices

This is a continuing in-house effort to survey available computer input/output equipment and develop conceptual designs for implementing various advanced instructional features. Emphasis will be on the development and test of advanced, multi-dimensional display techniques and of new input devices which improve the efficiency of man-machine communication over that achievable using traditional keyboards.

(3) Simulator Instructional Features Design Guide

This effort will result in determination of the operational circumstances and conditions under which aircrew simulator instructional features optimize the achievement of specific training and performance requirements. The primary program objective is the presentation of these data in an engineering guide for use by personnel responsible for specification and procurement of aircrew training devices. This program will complement the use of the Behavioral Data Design Guide task described below, thereby providing the user with more complete guidelines for the design of effective, low cost training devices. Instructional features with possible high payoffs will be identified for development under the Simulator Instructional Features Development task, below.

(4) Simulator Instructional Features

Development

This project involves engineering development and evaluation of instructional features for inclusion in operational and production simulators. Selected instructional features with possible high payoffs as identified by AFHRL and the Using Commands will be integrated into operational Air Force simulators and evaluated for possible retrofit or application to production simulators.

e. Modeling and Computation

(1) Simulator Tolerances

This effort will revaluate currently used simulator testing tolerances in an effort to tighten tolerances, where necessary and possible, to improve flight fidelity and to lessen tolerances, where possible, to eliminate oversimulation so as to reduce acquisition costs.

(2) Simulator Testing Techniques

This is a continuing in-house effort to establish and develop rigorous objective testing techniques to encourage improvement of the quality of simulators by improving the efficiency of the testing and verification procedures.

(3) Simulator Higher Order Languages

This effort will determine appropriate modifications to existing high order languages such as FORTRAN in order to improve their efficiency for real time simulation uses. Also, various parts of typical simulation problems will be analyzed to determine their amenability to real time high order language simulation.

(4) Advanced Computational Techniques

This effort will develop and evaluate advanced computer and software techniques for meeting existing and anticipated simulation requirements. This includes advancements in computational system designs, memory management techniques, and software partitioning schemes. It also involves optimizing compilers, computer memory devices, multiprocessor real time monitors, input/output programming and bussing, computer networking, and communications processing.

(5) Central Versus Distributed Computers

A requirement has been identified to initially develop a set of criteria which relate advantages/disadvantages of central versus distributed general purpose computer configurations in real time tr 'ing simulators. These criteria would then be formu d into a model. The model would accept as inputs a set of simulator system-level requirements, including acquisition, development, operation, maintenance, commonality, and standardization considerations. The model would output the relative merits of central versus distributed computer configurations for the particular simulator. The product of this effort would be used in the conceptual definition of training system configurations.

(6) Simulation of On-Board Avionics Software

With the expanded use of on-board programmable computers, a need exists to identify information processing requirements and computational approaches to incorporate computer program driven avionics systems performance in the training simulator. An in-house effort has been initiated to define specific on-board flight softwar' related training requirements and analyze alterrative approaches to meeting these requirements. Several approaches have been implemented on previous Air Force and Navy programs with varying degrees of success in terms of development risk, instructional and operational restrictions, and ease of modification and incorporation of changes into the simulator.

(7) Hardware Versus Software Implementation of Specific Functions

An effort has been initiated to identify candidate functions which may be designed and developed with hardwired or fixed microelectronic digital processors. Functions to be considered will include trignometric, transcendental, matrix manipulation, linear function interpolation routines, and input/output processing. Within the total simulator system there are many information processing elements which are common within a given simulator and across several simulators. The objective of this effort is to identify these and define standard requirements and potentially achieve standard electronics modules. Application of microprocessor technology will be included in this effort.

(8) Standardize Software Development Task Definitions

There has been inconsistency and ambiguity in the definition of "software development" related tasks. It is essential to the engineering and management acquisition efforts that software related work tasks be defined consistently from one simulator program to the next. To this extent, the component tasks of software development will be identified and specifically defined to include such activities as analysis, modeling design, equation formulation, flow diagramming, coding, checkout, debug, and levels of test and integration. The disciplines of mathematical, engineering, and programming design, along with configuration management, data management, and cost reporting must also be identified and defined as part of this effort to consistently identify and define the software development process. This effort will be conducted in-house and coordinated with industry with the intent of incorporating standard definitions into the Contract, Statement of Work, and Request for Proposals.

(9) ASD Regulation for Simulator Computer Systems Acquisition

Air Force Regulation 800-14 "Acquisition Management - Management of Computer Resources in Systems" has been published. Since this Regulation covers all systems acquired under the 800 series, it is somewhat general by necessity. A need exists to prepare an ASD training simulator supplement to this Regulation. This supplement will be drafted in-house to define specific acquisition policy and direction for computer resources; i.e., equipment and computer programs in training simulators.

(10) High Order Language Applicability

An AFSC level effort was initiated to analyze information processing requirements associated with all defense system applications. This effort included an analysis of training simulator software requirements. A preliminary historical analysis was prepared by ASD and submitted to ESD, the designated project manager. This effort is continuing with further analysis of simulator language requirements including review with industry. At this point, it is evident that FORTRAN can be successfully and economically used in the many real time computation requirements for training simulation.

(11) Computer Programming Techniques

An effort has been identified to analyze and develop systematic software acquisition and programming techniques such as structuring programming, thread concepts and standard computer program modules. Real time simulator FORTRAN techniques will also be developed as part of this effort. A bench mark will be used to investigate and establish programming techniques. The product of this effort will be requirements definition and standardization to be applied in writing Part I - Specifications.

(12) Computer Selection Model

The computer selection model delivered as part of the Aircraft Simulator Commonality Study, Task I(2), described later, will be restructured to reflect the emphasis of computer programming high order language considerations for use in definition of requirements and evaluation of proposals in source selection.

f. Simulation Requirement Validation and Specification

(1) Behavioral Data in Design Guide

This effort is a direct outgrowth and expanded application of the methodology used in the Functional Integrated Systems Trainer, F-106 MA-1A Attack Radar Trainer, and the Aerial Gunnery Part Task Trainer development programs. Major objectives of the proposed program are the development, updating, and refinement of strategies for the use of behavioral data for the design of low cost, high fidelity aircrew and maintenance training devices. The study effort will involve assessment and integration of current and future technology and applications of behavioral data in training device design. The primary program objective will be the compilation of a design guide on application of behavioral data for use by engineering personnel responsible for the design and specification of training devices.

(2) Aircraft Simulator Commonality Study

This effort will attempt to determine areas in which common hardware and software may be acquired for future Air Force simulator systems, and it involves two tasks. Task 1 is an ASD in-house analysis of current and projected requirements for aircraft simulator systems to identify commonalities in the requirements. Task 2, composed of four subtasks, is a combined AFSC in-house and contractual effort to identify those areas where commonality is feasible and practical.

(a) Simulation Data is an in-house evaluation of the requirement for simulator data items procured in recent simulator contracts to ascertain whether data procurement cost is commensurate with its benefits.

(b) Mathematical Terminology and Symbology is an in-house review of flight performance and engine modeling systems used by simulator manufacturers and will lead to a standard specifying a standard set of symbology and terminology.

(c) Aircraft Data will be a contractual effort designed to derive the requirements for a total weapon system simulation data package that normally would be developed by the aircraft manufacturer and result in a general specification for aircraft data procurement.

(d) Computer Organization and Documentation is a contractual effort to determine a standard or common set of criteria organized as a computer model which will serve as a tool for weighing the relative merits of various candidate computation system configurations. The computer model has been delivered to ASD and is currently undergoing evaluation.

g. Simulation Application/Evaluation

(1) F-106 MA-1 Attack Radar Trainer

This program is being conducted for the Aerospace Defense Command (ADC) and is intended to develop a part task trainer device capable of providing training in use and operation of the F-106 MA-1 radar. The primary objective of the effort is further refinement and validation of the use of behavioral task analysis data to precisely define trainer device requirements. A training effectiveness evaluation to determine validity of the technique will be conducted subsequent to installation and utilization of the device to provide data previously developed compared with that of the Functional Integrated System Trainer (FIST).

(2) Aerial Gunnery Part Task Trainer (AGPTT)

The primary objective of the AGPTT study is also that of further validation and refinement of the use of behavioral data for design of training devices. The AGPTT will provide training in the final portions of the aerial gunnery mission. The method of behavioral data acquisition for the AGPTT is somewhat different than that used in the FIST and that being tested in the F-106 trainer. The AGPTT program will utilize a direct questionnaire/interview approach to gather behavioral data rather than the more extensive task analysis methods previously applied. The feasibility and validity of the AGPTT behavioral data methodology will also be evaluated through a training effectiveness study conducted during actual utilization of the trainer.

(3) Advanced Systems Exploitation

Four major Air Force advanced simulation system developments have been or are nearing completion: the Advanced Simualtor for Undergraduate Pilot Training (ASUPT), the Simulator for Air-to-Air Combat (SAAC), the F-4E Simulator #18, and the Digital Radar Landmass Simulator (DRLMS). These programs undoubtedly will have a profound influence on procurements of future simulators and trainers. Tests, experiments and evaluations of the resultant hardware and software are being directed toward attaining greater insight into optimum configurations and their relationship to human learning and training transfer. Figure II-4 shows the planning schedule for these programs. These programs are of particular importance because of their

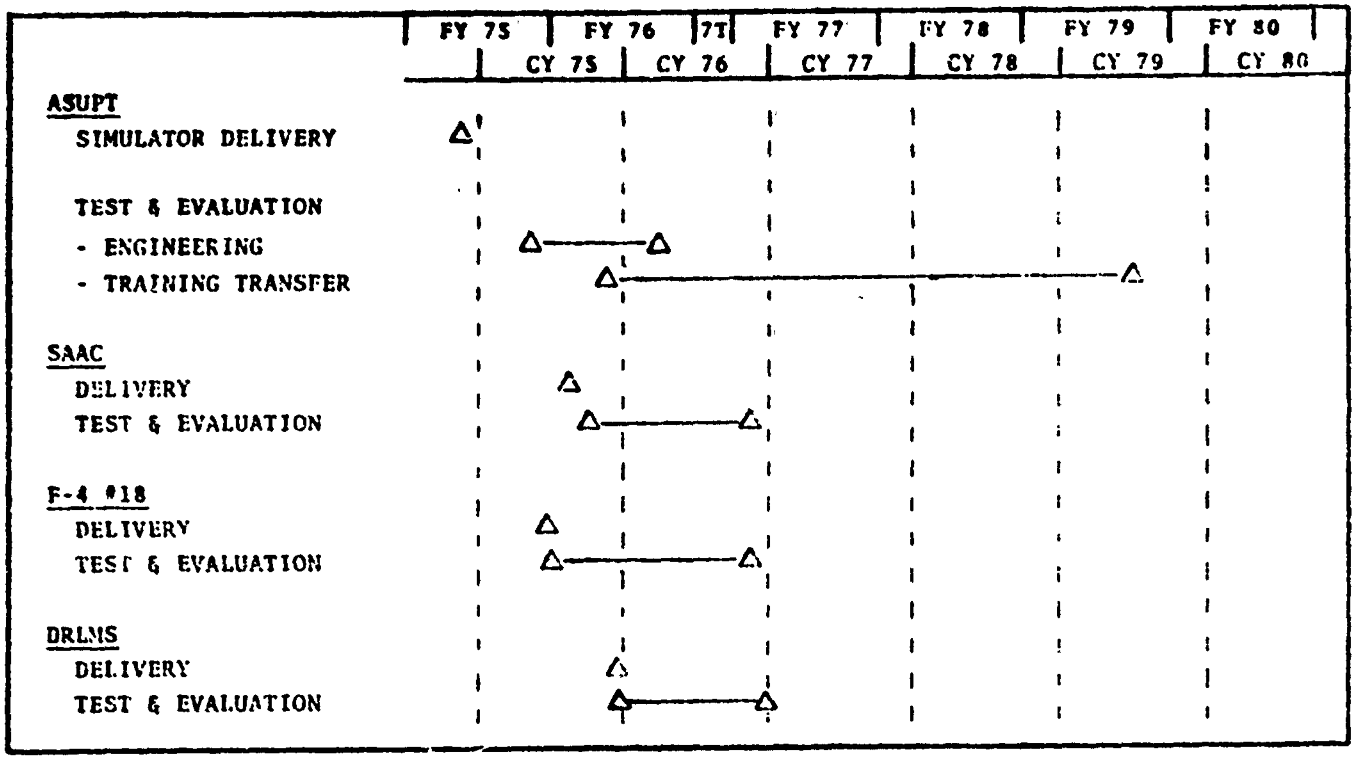


FIGURE II-4. SIMULATOR ADVANCED DEVELOPMENT PROGRAMS influence in the decision process regarding the procurement of simulators to meet MAJCOM needs. The four major programs encompass much of the advanced development activity needed to ensure viable simulator programs over the next decade. Therefore, the procurement of future simulators to fully satisfy Command needs is predicated on successful completion of at least DT&E/IOT&E for these major programs.

(a) ASUPT Utilization

The Advanced Simulator for Undergraduate Pilot Training (ASUPT) is now installed at Williams AFB. The F-4 #18 and the Simulator for Air-to-Air Combat are at Luke AFB. In addition, the visually equipped C-5/C-141 simulators at Altus AFB will be available in late FY 76 for test and evaluation. These advanced development programs could form the nucleus for AFHRL/FT research to explore the broad range of training and simulation issues which cut across MAJCOM areas of interest. Exploration of simulated motion and visual cues, computer generated imagery, and the effects of force cues in augmenting motion sensing will impact on all CCTS and continuation training in addition to undergraduate pilot training. There is a need as well to "get with the user and help him solve his problems" as admonished by General Ferguson in 1968. Thus, there is a planned activity for MAJCOM support of their priority programs.

A major program is planned around the capabilities of the ASUPT as a research tool. It has been designed with research exploitation in mind and is admirably suited to this task. It provides the capability for selective task sequencing, variable task difficulty, selective malfunction insertion, freeze, rapid reinitiation, automated demonstration, self confrontation display, and computer aided instruction. In addition, the six degree of freedom motion system can be restricted to any combination of the six degrees of freedom desired; variation of aerodynamic response to control movement is possible and, of course, the visual display may be used fully or the scene restricted to suit testing purposes. Since the system uses computer generated imagery, this technique of vital interest can also be subjected to close examination.

The flexibility of this research tool permits several research approaches. Present planning envisions an approach which will take full advantage of the ASUPT capabilities and produce data for decision on future procurements in a timely manner. The research is planned to be conducted on four levels: (I) The study of the basic components of simulation; (II) the examination of the interactions of those components; (III) the experimental investigation of candidate simulator devices, and their substitutability for aircraft training; and lastly, (IV) the development of pilot training syllabi which incorporate the optimum mix of simulator and aircraft training.

Level I - These studies form the foundation of the research and will include examination of each major independent variable of simulation. The objective of Level I is to gather knowledge on the basic components of simulation. For research purposes, these components have been divided into two major classes; hardware design and training methods. Hardware components consist of the motion, visual, aural, and computer systems which make up the physical parts of the simulator. Training methods such as automatic demonstration, variations in task difficulty and sequencing, enhancement of feedback, and malfunction insertion are the intangible aspects of simulation which govern its use. Each of these areas will be studied separately in this first level and then in combination in a later level. (The hardware design research program will be discussed prior to that of training methods. However, the order in which the studies are treated is not necessarily the order in which they will be addressed during the actual research effort).

Hardware Research - The approach to hardware research will be a two-step process. The first part will be directed at establishing the kinds of component configurations to be examined, and the second part will consist of the systematic investigation of those component configurations in training. An example of hardware research is to use ASUPT to assess alternative primary motion cueing systems - three, five, and six degrees of freedom - with and without the g-seat. Such a systematically developed data base would identify the degree of freedom requirement for future simulator procurement or modification.

Training Methods Research - The approach to training methods research will involve evaluating the application of individual training methods to the simulator; for example, automatic demonstrations, variations in task difficulty, task sequencing, student feedback, instructor feedback, and malfunction insertion. These training methods will be examined individually to determine the qualities of each which contribute to or interfere with training.

The hardware and training methods categories of variables are highly interdependent. Effects of hardware cannot be studied without interaction involving training variables; nor can training be studied without interactions involving hardware variables. However, by manipulating only one category of variable at a time, the interactive effect can be controlled. To accomplish this, a fixed training method will be employed while studying hardware variables and a fixed hardware configuration will be used when studying training variables.

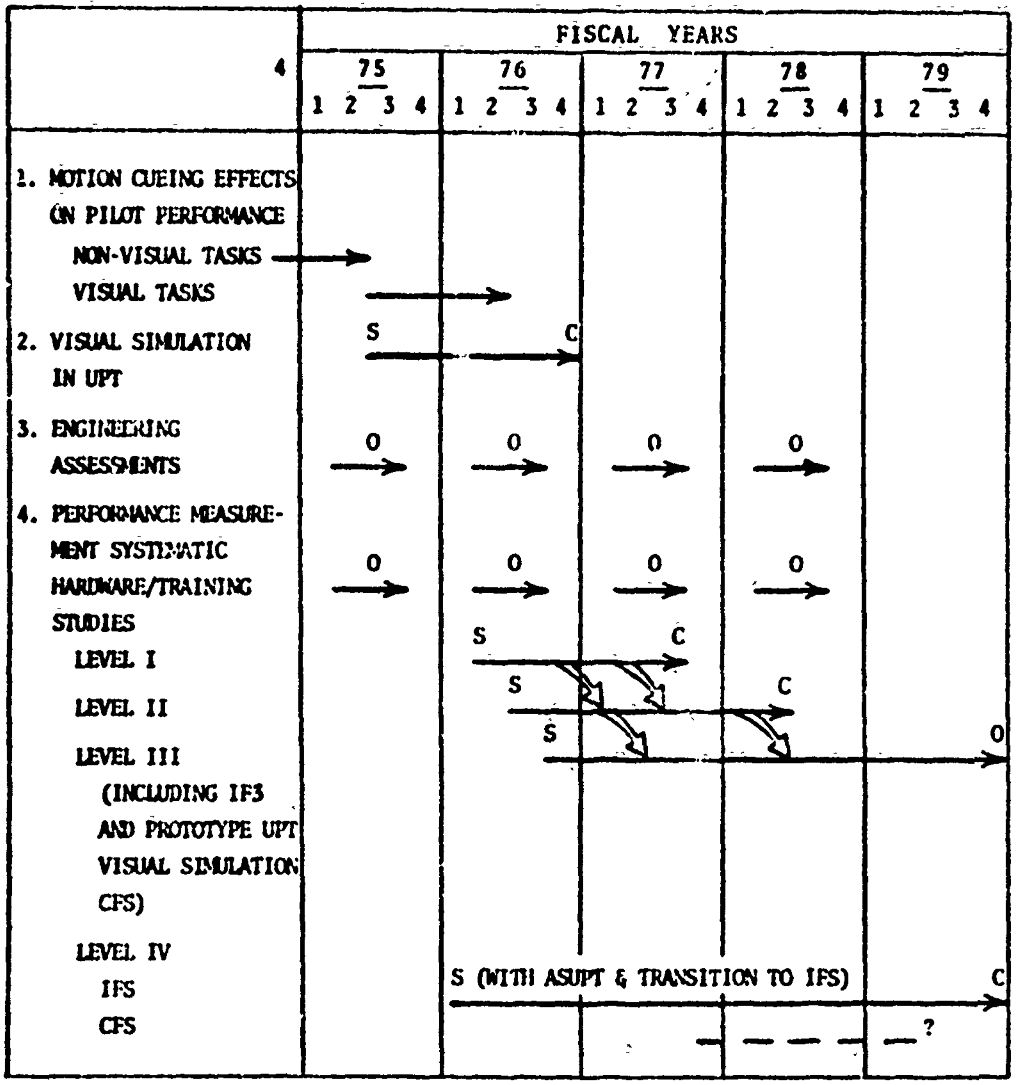
Level II - These studies will examine the interactive effects of the components of simulation. More specifically, how motion, vision, mathematical modeling, etc., interact to impact device training effectiveness will be examined. Another purpose of this stage will be to study the way in which training methods such as knowledge of results and computer aided instruction interact to influence training effectiveness. The specific interactions chosen for examination will be determined based upon data obtained during the first phase of the program, considerations of the combinations, additional factors such as recommendations for research from the UPT studies, and the length of time required to collect the needed data.

Level III - These studies will involve investigation of candidate simulator configurations and their interaction with training methods. These candidate configurations will consist of combinations of hardware components found in Level II research to have the highest probability of being cost effective in the UPT program. One of the primary concerns of this stage of the research program will be the relationship between simulator configuration and training value as a function of time in the simulator. Interacting with this relationship is the training method employed during the time the student is in the simulator. Hence, the "simulators" studied at this time will be examined in a three-way interaction of device configuration, training method, and time. The studies will be essentially a rigorous evaluation of several candidate simulation systems. The results of this stage of the effort will provide information as to the most likely cost effective simulator or family of devices for implementation in UPT. This also will involve the study of substitutability, which is the first step in determining the most productive utilization of that hardware within the operational training environment. The procedure for determining substitutability will be to insert simulator training into various areas of the flying curriculum in place of aircraft training. The amount of simulator training will be varied in order to acquire a measure of the amount of aircraft training that can be replaced by the simulator. The results of this stage will provide information on the effectiveness of simulation within the major phases of T-37 pilot training.

Level IV - Level IV training syllabus development has as its purpose the study of the complex interrelationships between amount, content, and sequence of simulator/aircraft training. The procedure to be employed will require the examination of the previously identified simulator system within the entire primary jet training phase of the UPT program. Follow-on studies will be conducted to monitor the progress of simulator trained students through advanced jet training and combat crew training. From these syllabus development studies will come recommendations for the effective utilization of the complete simulator hardware system defined during the preceding four stages of research.

The utilization of the ASUPT in terms of major task areas to be undertaken are depicted in Figure II-5. The numbering of these tasks indicates the priority established. It should be noted that only the ASUPT work is within present AFHRL/FT capability. It will require approximately 26 professional man-years and $1,700,000 per year for ASUPT O&M. All other work will require added manpower and dollars.

(b) F-4E #18 Utilization - The F-4E #18 Simulator was delivered to Luke AFB in February 1975. Both this simulator and the SAAC have been developed to address the unique visual and motion requirements of air-to-ground and air-to-air fighter pilot training. Although both have six degree of freedom synergistic motion systems, their most significant features are their visual systems. Both are the culmination of long standing R&D efforts to develop image generation and display subsystems which would provide the image content and field of view required for fighter



S = START

C = COMPLETE

O = CONTINUING

* REQUIRES 26 MAN-YEARS AND $1,700,000 PER YEAR

FIGURE II-5. ASUPT UTILIZATION *

simulators. The F-4E #18 is currently undergoing a three-phased OT&E to determine the capabilities, operational effectiveness, operational suitability and logistic supportability of WSTS-18 to satisfy simulation training needs in takeoff/landing, aerial maneuvers, and air-to-ground weapon delivery, and to define requirements for future TAC simulation. Phase I, now underway, is directed at OT&E of the basic simulator system with preliminary evaluation of the instructional features of the system. Phase II will consist of an assessment of the operational training effectiveness of the simulator. Special emphasis will be placed on deriving the necessary input information to facilitate evaluation of simulator training effectiveness in greater depth. Phase III will be an OT&E of added advanced simulation capabilities during the late 1976 to 1977 time frame.

(c) SAAC Utilization - The SAAC was delivered to Luke AFB in April 1975 and is now undergoing tests similar to the F-4E #18. A two-phased IOT&E will be conducted starting in late CY 75. Phase I of a two-phased IOT&E is now underway. It is directed at the basic simulator system with preliminary evaluation of the instructional features of the system. Special emphasis will be placed on acquiring baseline system capabilities information to facilitate evaluation of simulator training effectiveness in greater depth during Phase II. Phase II is designed to determine operational suitability, training effectiveness and training application of the simulator for acquisition and maintenance of air-to-air task skills as well as tactics development.

(d) DRLMS Utilization - The Project 1183 DRLMS will be delivered to Nellis AFB in January 1976, and will be followed by a one year period of DT&E/IOT&E. The current technology for simulating radar landmass is considered to be deficient. Research will be conducted with the DRLMS to determine if it can provide an improved simulation and training capability over existing systems and to identify what tradeoffs of DRLMS capabilities can be made without compromising realistic radar simulation for training.

4. Major Command Support

AFHRL support to ADC, ATC, MAC, SAC, and TAC is projected over the FY 76-80 time frame to encompass providing consultative assistance, assistance in specification revisions, conducting training research, and participating in OT&E.

a. Activities in the Support Areas

(1) Consultation

- Defining training research problems,

- Developing RPRs, ROCs, and RFPs,

- Reviewing/evaluating RPRs, ROCs, and RFPs,

- Participating in MAJCOM special project planning meetings, and

- Applying training technology.

(2) Specification Revision

- Providing equipment acquisition assistance by attending the preliminary design review, critical design review, and significant program reviews, and

- Suggesting changes in specifications to optimize equipment effectiveness in training.

(3) Training Research

- Performing studies identified in formal requests, and

- Providing interim and final reports.

(4) OT&E

- Attending OT&E planning meetings,

- Participating in development of the OT&E plan,

- Performing specific training evaluation tasks to accomplish objectives identified in the OT&E plan, and

- Participating in development of OT&E Report.

b. MAJCOM Requirements for Support

(1) Aerospace Defense Command (ADC)

At the present time ADC has no validated RPRs. However, ADC has identified a substantial number of requirements to support plans for improvement in flying training and weapons controller training. These requirements, with time phasing, are provided in Figure II-6a. The estimated costs of AFHRL support for all of the ADC requirements are identified in Annex A.

(2) Air Training Command (ATC)

ATC has nine validated RPRs identifying requirements in the area of flying training research which are now being supported by AFHRL. Three more ATC RPRs have been submitted and are now in the coordination (review and validation) process. AFHRL is also providing substantial consultative assistance to ATC. In addition, the main thrust of the research with ASUPT will be directed toward ATC training applications. A listing of present and projected ATC requirements is provided to Figure II-6b. The estimated costs of AFHRL support for these requirements are identified in Annex A.

(3) Military Airlift Command (MAC)

At the present time MAC has one validated RPR. However, the AFHRL support to MAC is primarily consultative. A listing of projected MAC requirements is contained in Figure II-6c. The estimated costs of AFHRL support for these requirements are identified in Annex A.

(4) Strategic Air Command (SAC)

SAC currently has one validated RPR and four SAC ROCs which also serve to delineate some of the SAC research requirements. At the present time, however, AFHRL support to SAC is primarily consultative. A listing of projected SAC requirements is contained in Figure II-6d. The estimated costs of AFHRL support for these projected requirements are identified in Annex A.

(5) Tactical Air Command (TAC)

TAC has seven validated RPRs identifying requirements in the area of flying training research which

ADC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

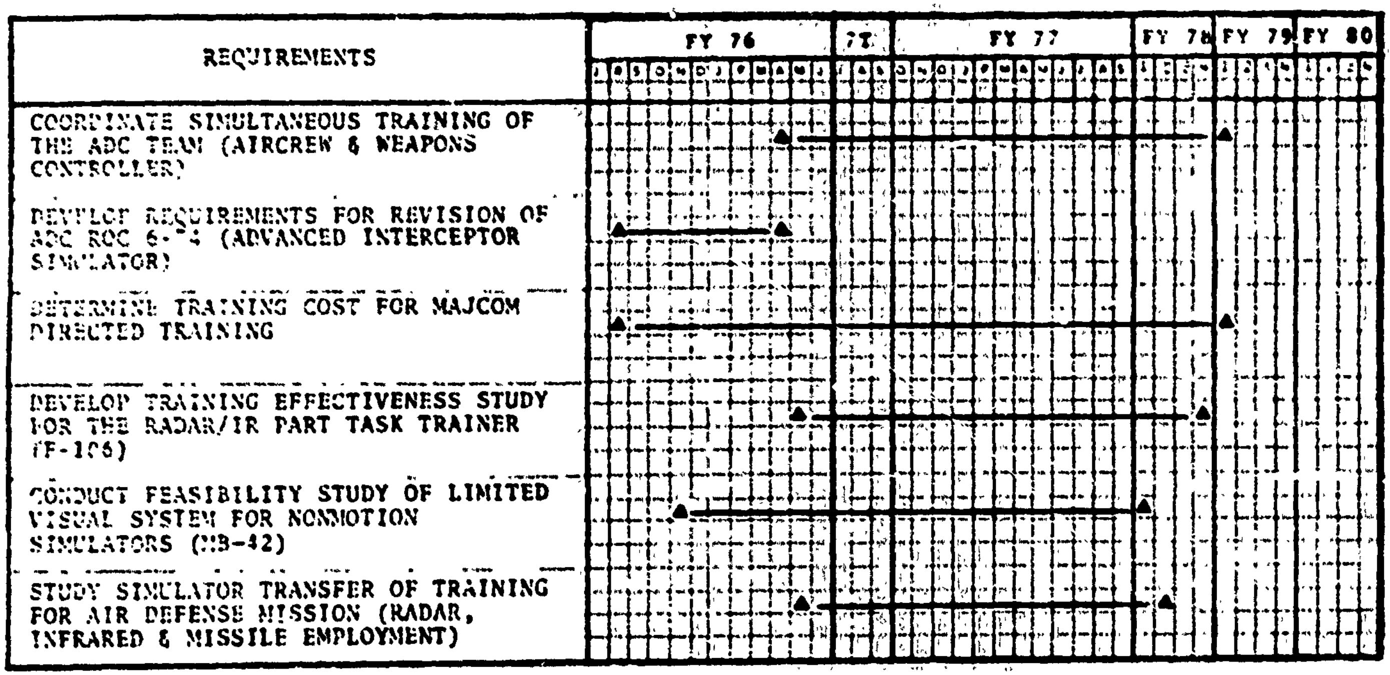


FIGURE II-6A

ADC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

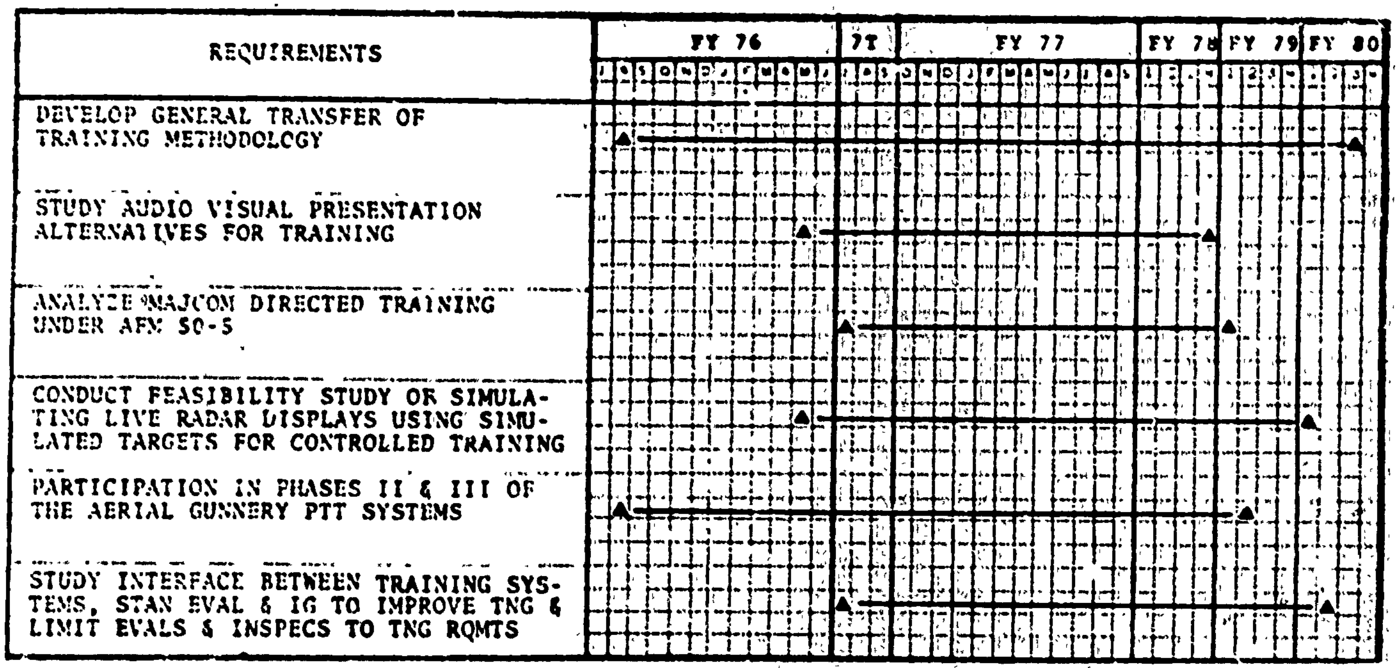


FIGURE II-6A (CONTINUED)

ATC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

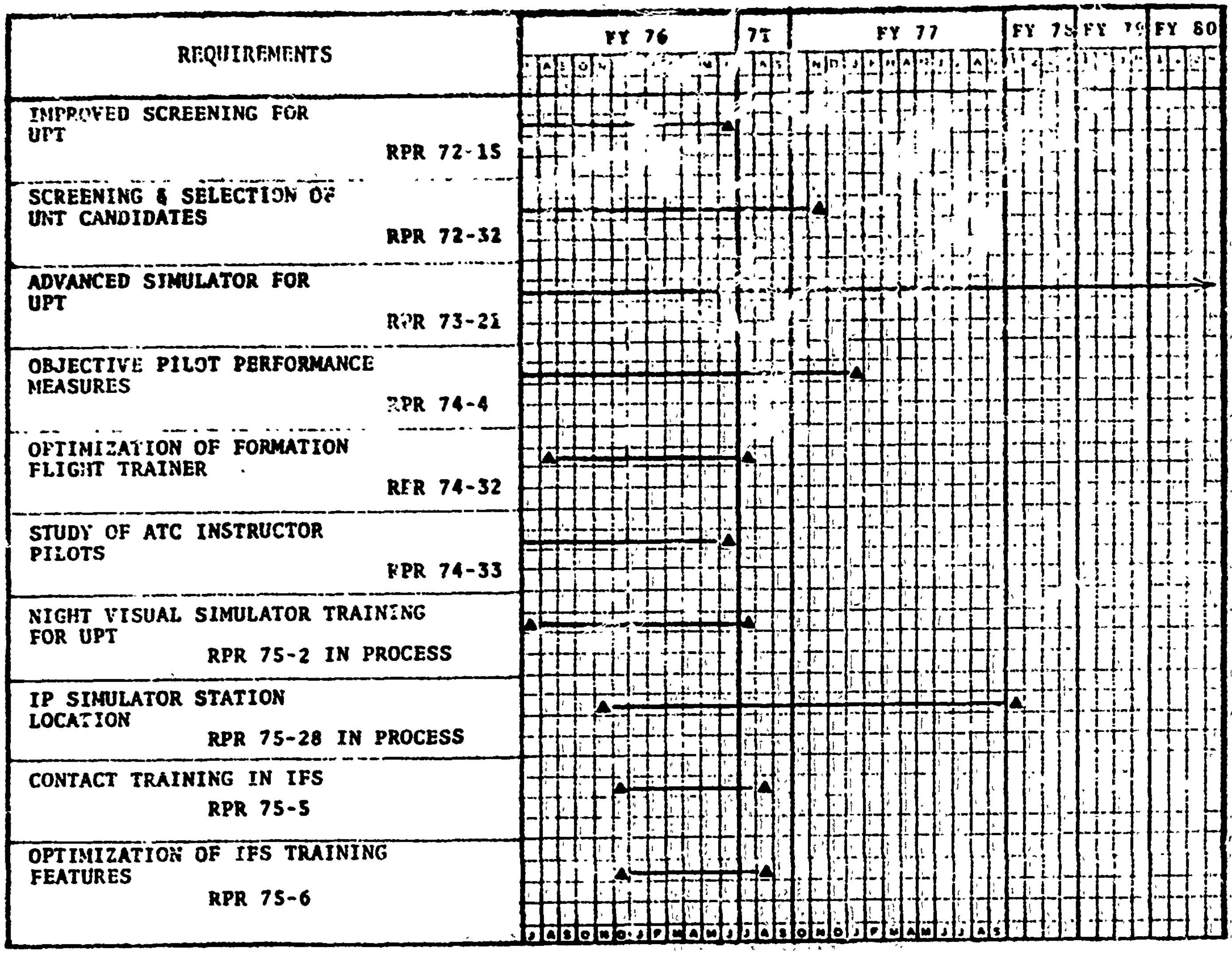


FIGURE II-6B

ATC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

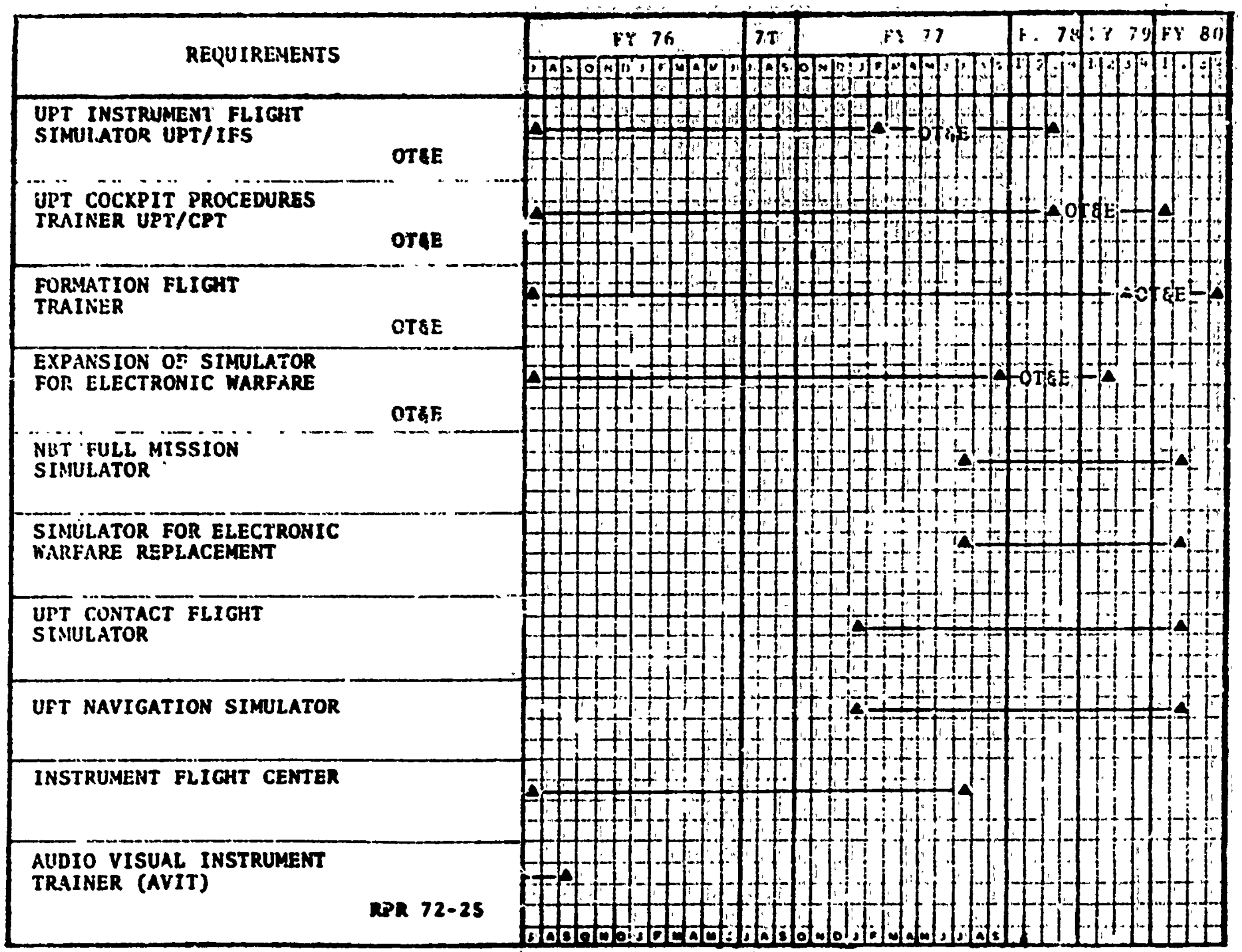


FIGURE II-6B (CONTINUED)

MAC REQUIREMENTS
(PLACED IN ORDER OF COMMAND PRIORITY)

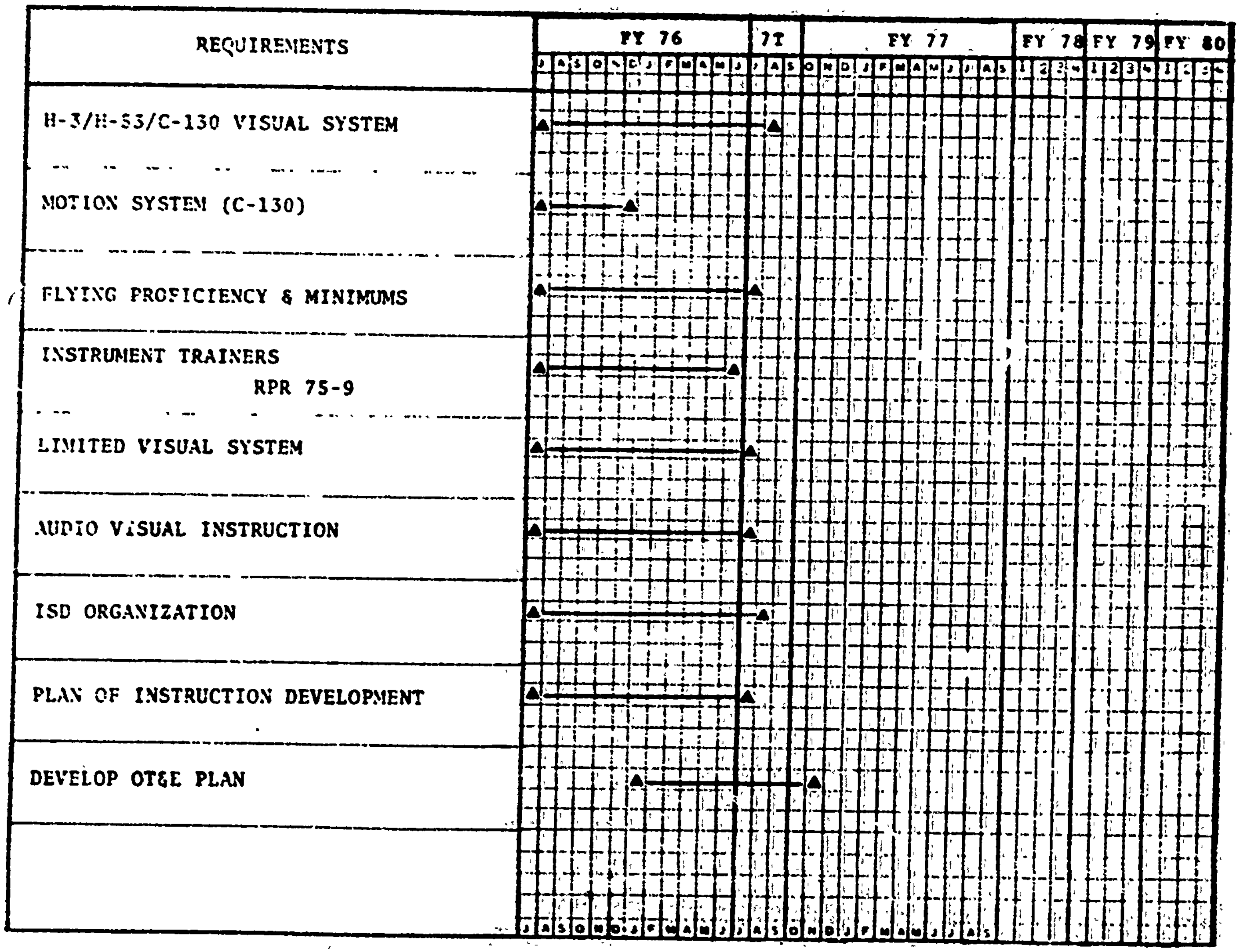


FIGURE II-6c

MAC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

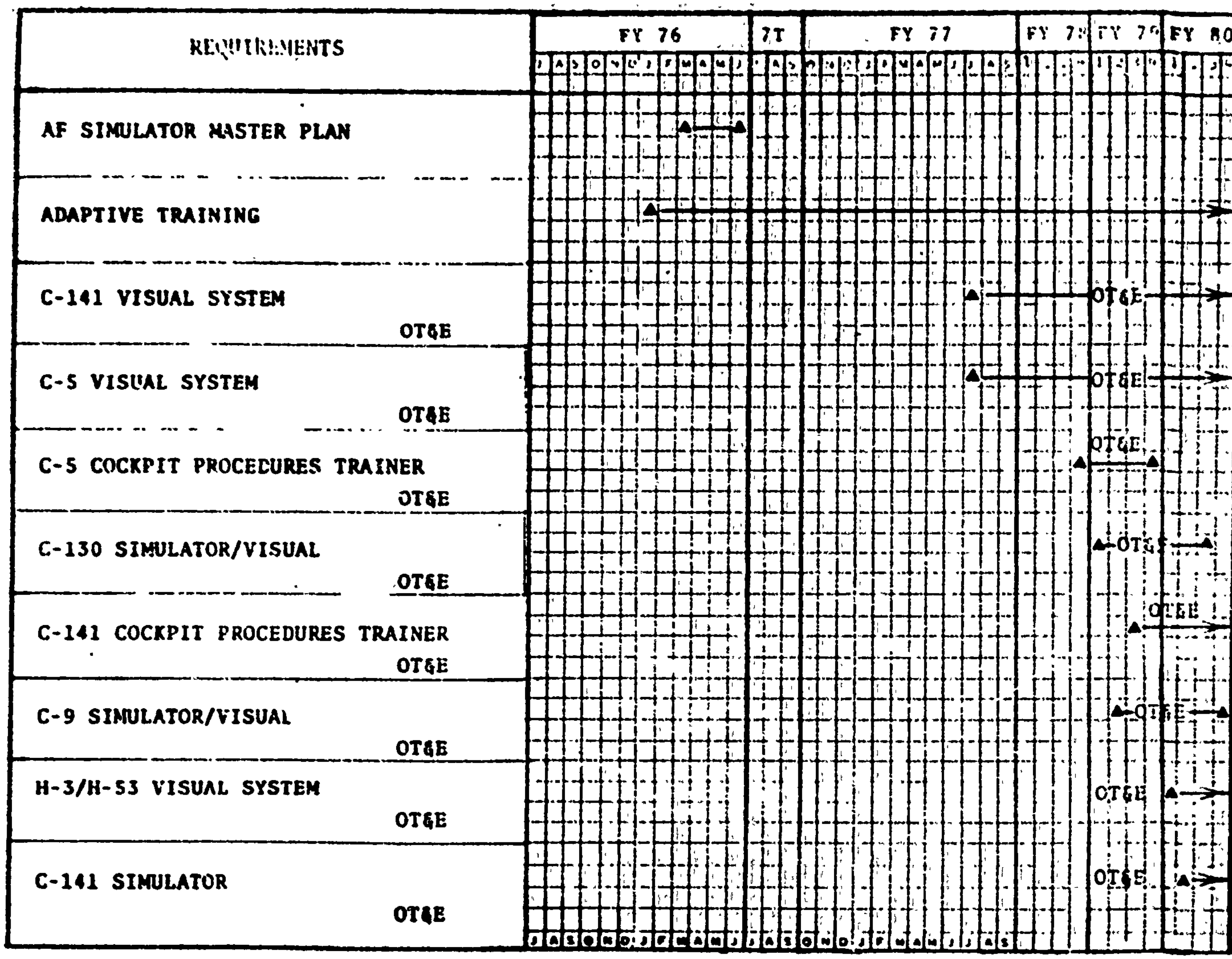


FIGURE II-6c (CONTINUED)

SAC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

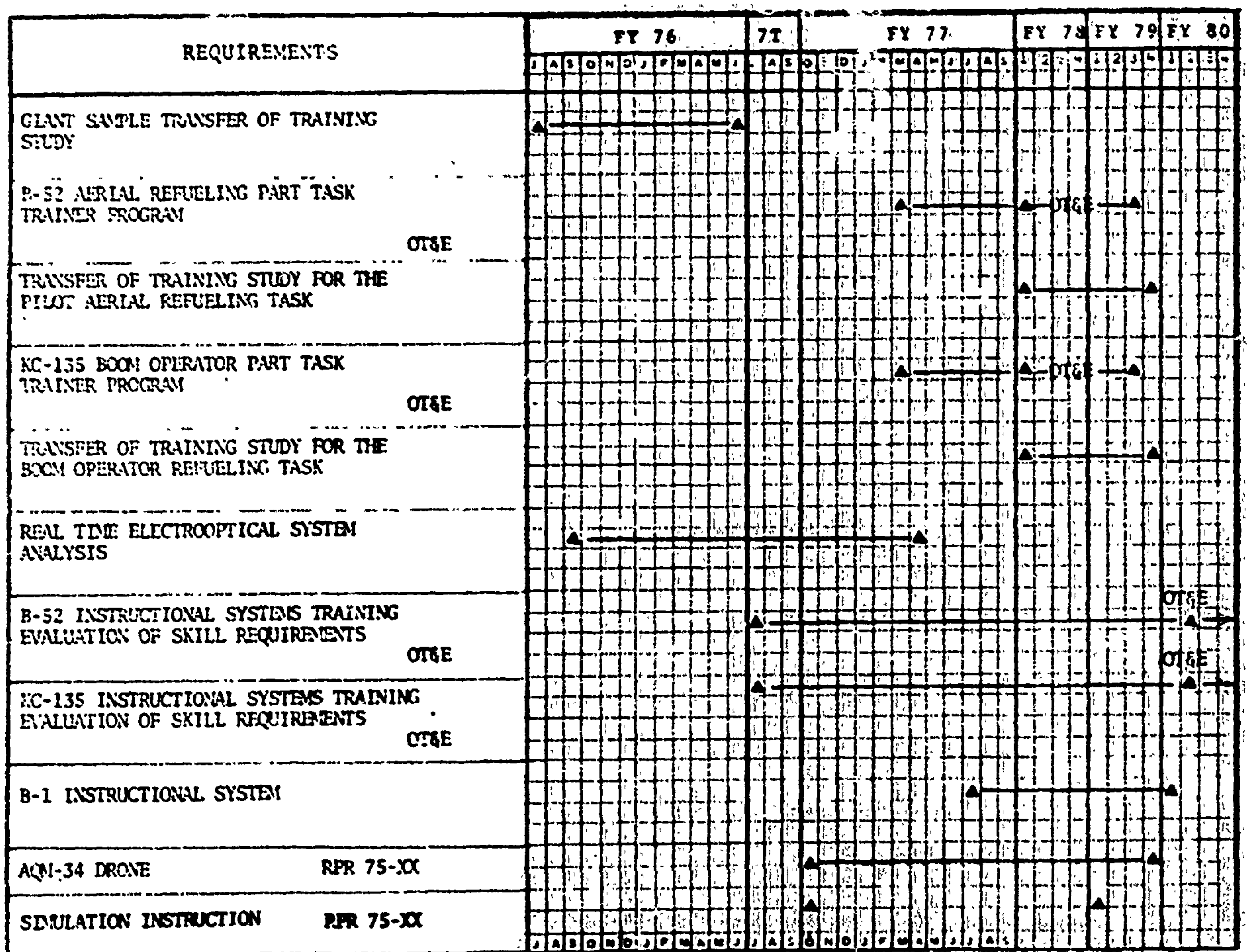


FIGURE II-6D

TAC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

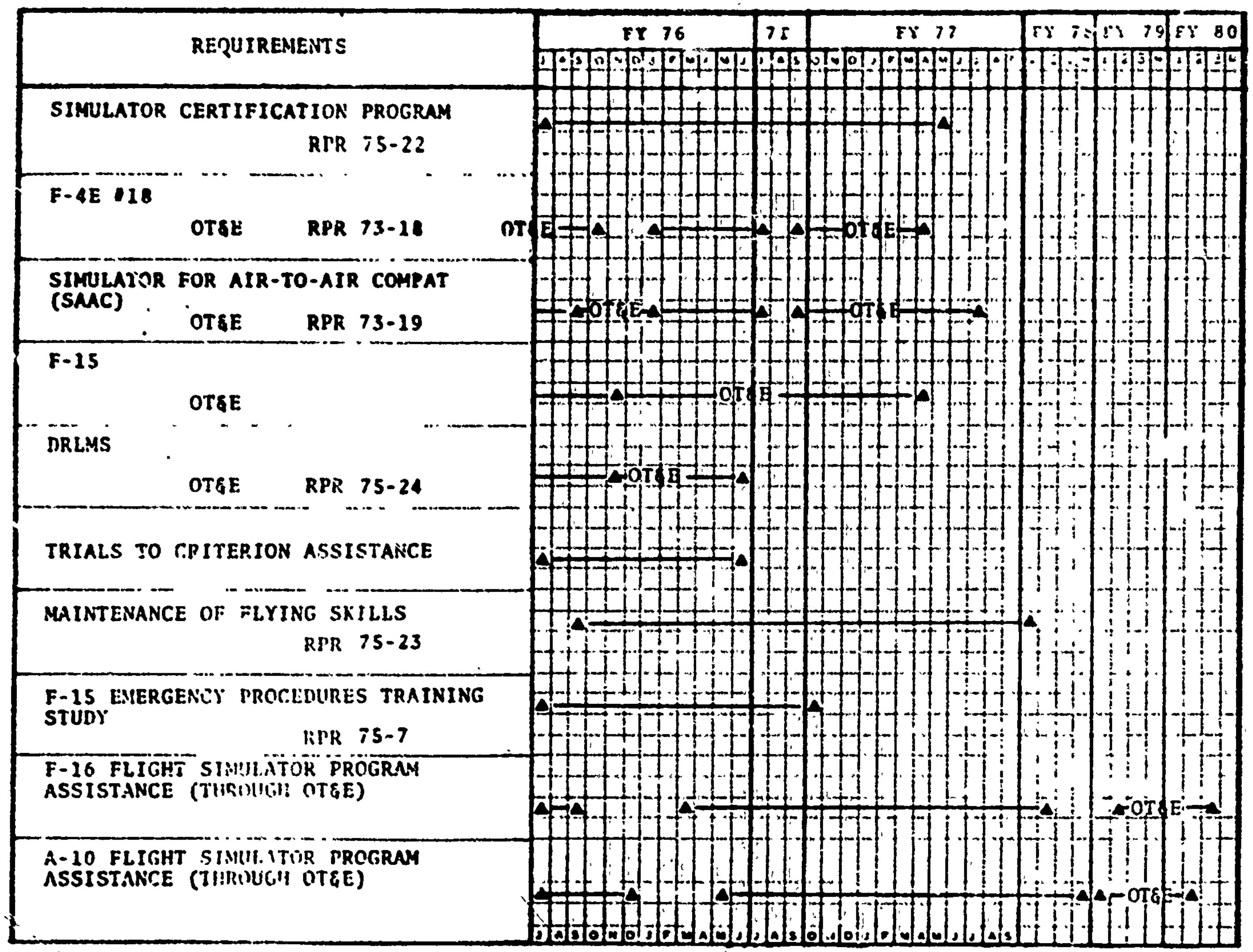


FIGURE II-6E

TAC REQUIREMENTS

(PLACED IN ORDER OF COMMAND PRIORITY)

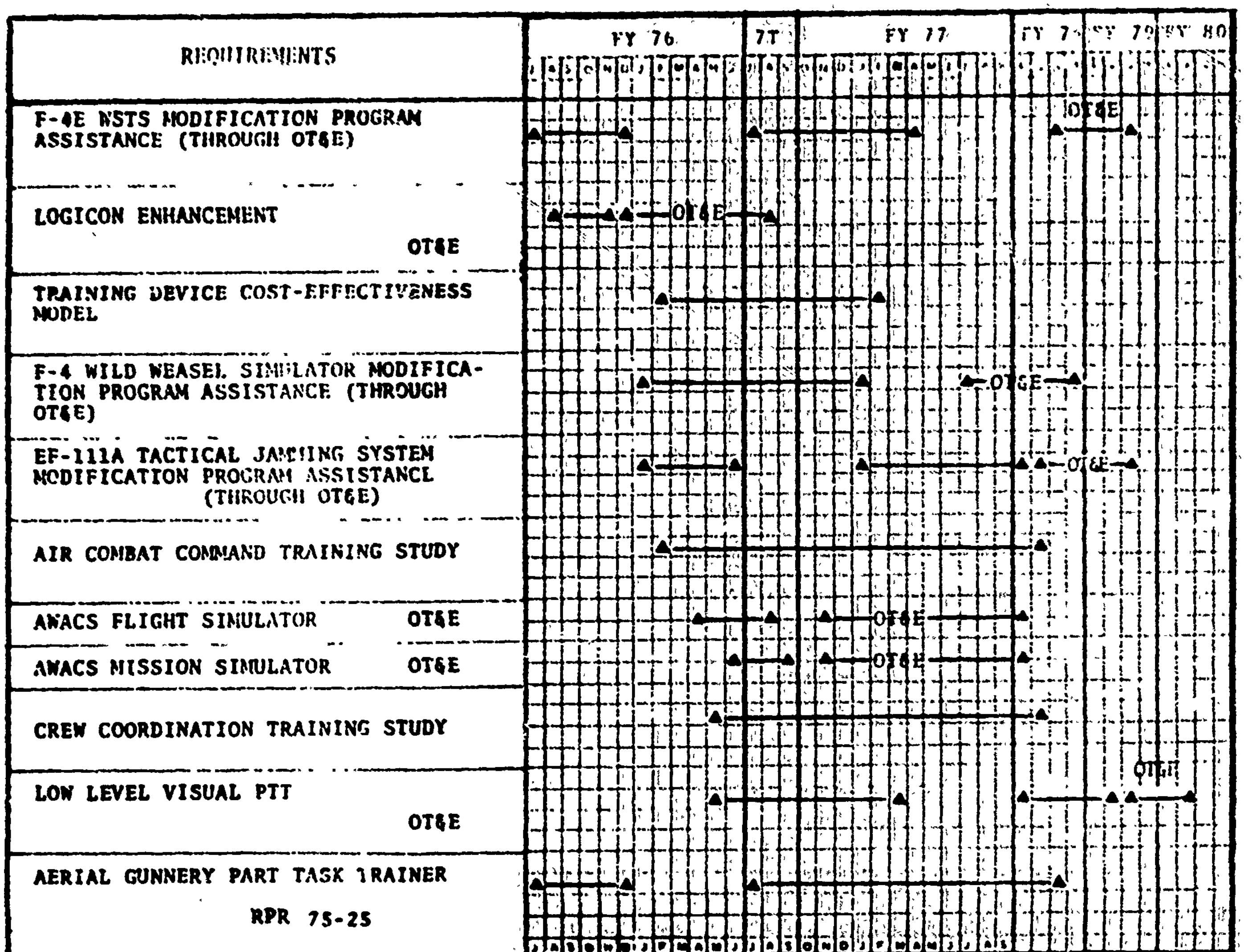


FIGURE II-6E (CONTINUED)

MAJCOM OT&E REQUIREMENTS

(LISTED IN ORDER OF THE CURRENTLY SCHEDULED EVALUATION)

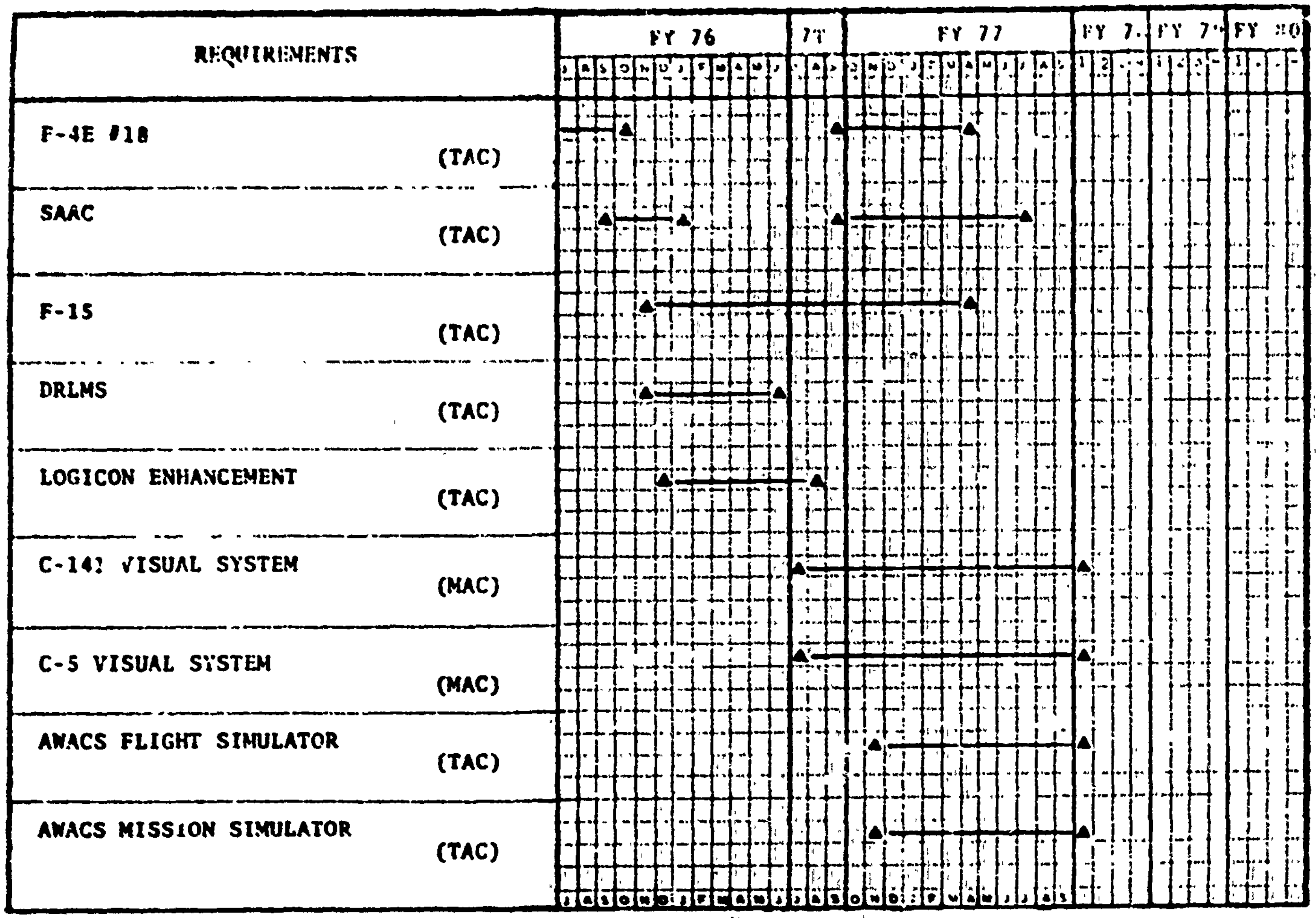


FIGURE II-7

MAJCOM OT&E REQUIREMENTS

(LISTED IN ORDER OF THE CURRENTLY SCHEDULED EVALUATION)

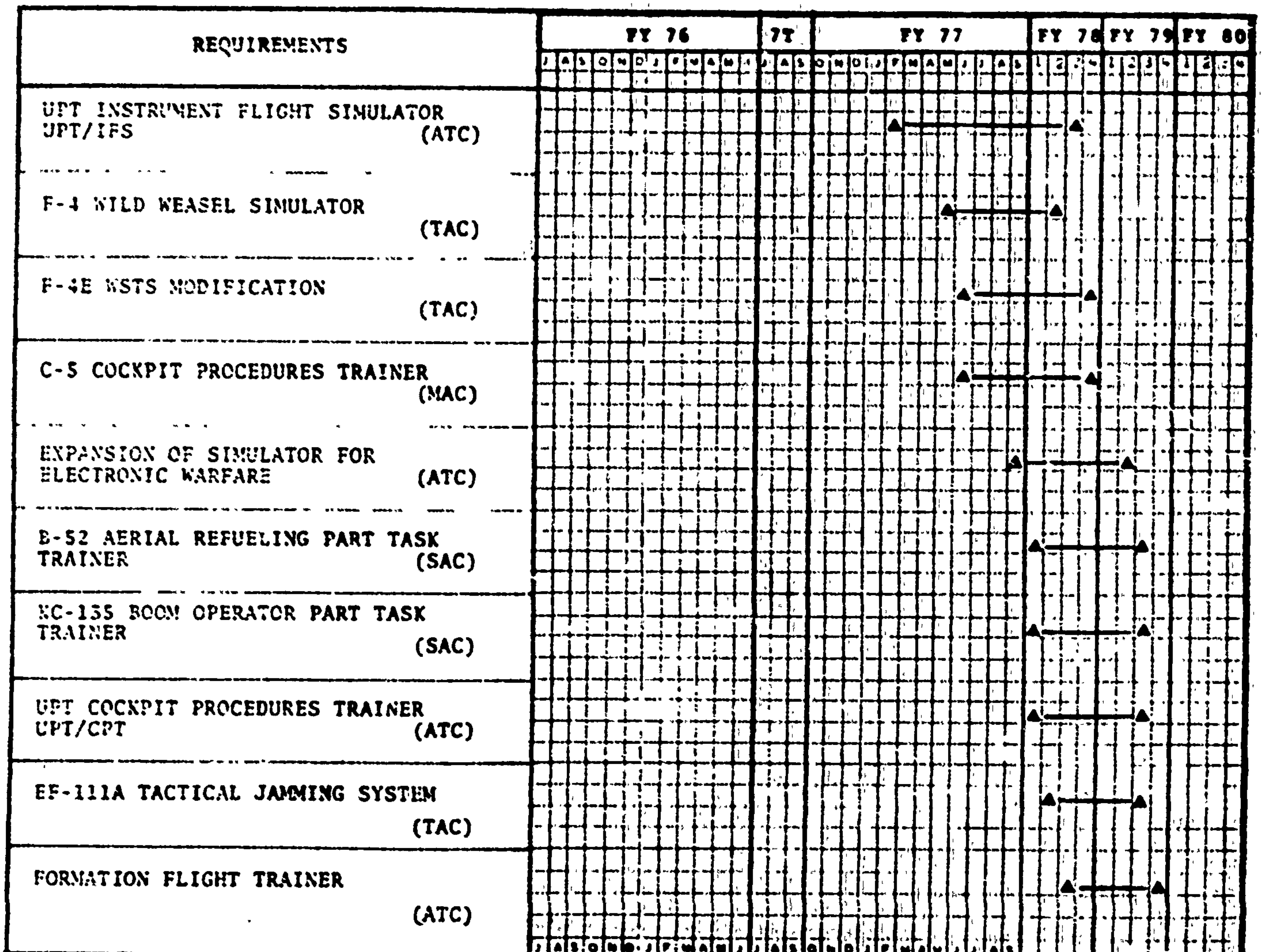


FIGURE II-7 (CONTINUED)

MAJCOM OT&E REQUIREMENTS

(LISTED IN ORDER OF THE CURRENTLY SCHEDULED EVALUATION)

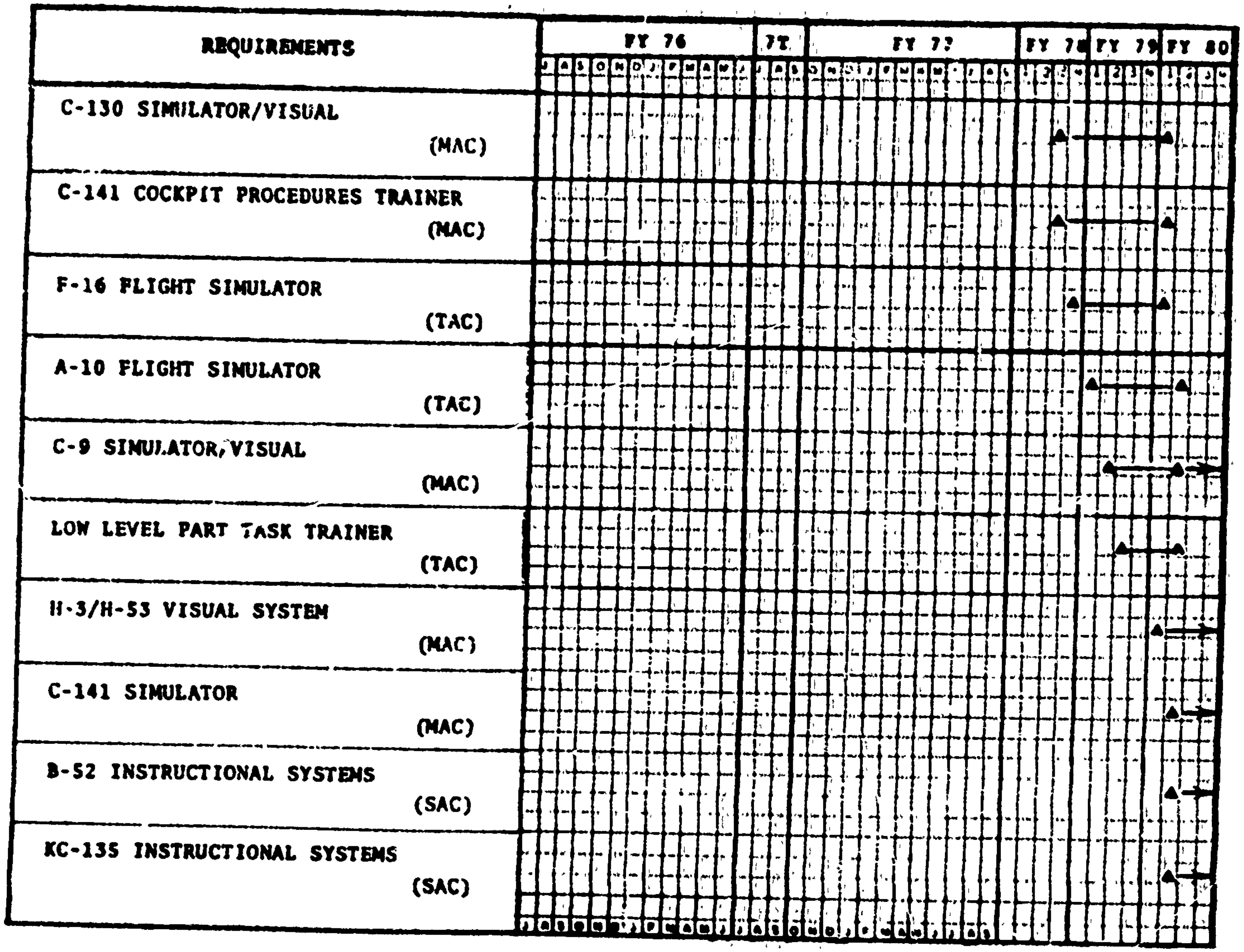


FIGURE II-7 (CONTINUED)

are now being supported by AFHRL. Also, TAC has more RPRs in coordination which are expected to be validated in FY 76. At the present time, AFHRL is providing considerable consultative assistance to TAC for the Simulator Certification Program and OT&Es. A listing of present and projected TAC requirements is provided in Figure II-e. The estimated costs of AFHRL support for these requirements are identified in Annex A.

c. MAJCOM OT&E Requirements Summary

The OT&E requirements listed by MAJCOM in Figures II-6a through II-6e are consolidated in Figure II-7 to show the magnitude of the OT&E effort for AFHRL and identify the MAJCOM scheduled evaluation. As a general rule, eighteen months was used as the OT&E period (four months for assessment of equipment capabilities and fourteen months for training evaluation). It should be understood, however, that AFHRL must interact with the MAJCOM prior to the OT&E start date to assist in developing the OT&E plan (estimated to require periodic consultation/assistance over a six month period). Finally, each OT&E will require a final report which should fall due on or about the end of the OT&E period. It is anticipated that AFHRL will be required to make significant contribution to such a final report or to write the entire training evaluation portion of the report.

Given the resources identified for MAJCOM support it is envisioned that at least one AFHRL research psychologist should be assigned duty at each of the MAJCOM Headquarters to provide the maximum degree of responsiveness to MAJCOM requirements and to assist in application of research findings.

SECTION III

PLANNING ISSUES

The Office of Management and Budget in their report of 26 July 1973 very succinctly put forth three critical issues in regard to the use of simulators in the Services: How much simulation is technically feasible? How much is militarily acceptable? How much is economically mandatory?

The preceding sections of this report have dealt largely with the first of these questions. There is little, if any, doubt that technology can produce simulators to accomplish any given training task given enough time and money. The question of how much will it cost, when can it be made available and which things should be done first belong to the realm of programs and are dealt with in the subsequent sections for each major Air Force Command on a weapon system by weapon system basis. The questions of military acceptability and economic drives and constraints are far more difficult to deal with because they require institutional changes and require data not in evidence to feel confident about the answers. The questions are, nevertheless, valid and useful in discussing what institutional changes are involved in moving further in the simulator area and how we can plan in the face of uncertainties. This section will deal with some of the relevant issues and attempt to set some directions and guidelines within which programs can have coherence and a greater chance of success.

Significant Command initiatives have been taken which recognize the value of synthetic training devices on their own merits and not principally as a surrogate of the aircraft. They have recognized that their unique training capabilities would continue to compel their increased usage regardless of the recent pressures to conserve fuel through reduced flying. The Military Airlift Command, for example, had established the requirements for their present training devices years in advance of the energy problem on the basis of improved efficiency and quality of training, safety and mission reliability. The Instructional System Development approach to the development of optimum training systems has been endorsed and is being aggressively pursued by all of the Major Air Commands. It is partially due to the recognition that simulators are but one aspect of a total training program that it is difficult and literally impossible to make definitive choices in advance of the completion of these efforts, and before the results of planned research is available. It is clear, however, that certain institutional changes will be required as the training medium of simulators becomes more and more prominent, and as their complexity and costs increase. There are also some general technological issues which should be recognized. While they do not represent impasses, overt attention to them will add coherence to future programs.

A. INSTITUTIONAL CHANGES REQUIRED

1. Regulation Changes

AFR 60-1 "Flight Management Policies" must be revised to allow some flying requirements to be accomplished in a simulator. Annual instrument checks and landings performed in simulators with visual systems are among the requirements which might be allowed under such a revision. This change implies that a procedure must be established for certification of simulators much as the FAA approval of simulators for commercial pilot training is done today. If credit is to be given for simulator time, the fidelity, flight dynamics and configuration of these devices must be evaluated on a regular basis to ensure adequate representation of flight in the simulated aircraft. Credited simulator time in lieu of annual fulfillment of training events could extend to both continuation training in the operating commands and proficiency training for flight crew members assigned to nonflying duty. This could significantly reduce proficiency flying and associated costs and would have two substantial benefits in addition: there would be an increase in the pool of qualified crew members for emergency or surge requirements in the rated force; and, it could allow more actual flying experience for younger crew members by removing more experienced (excused) flyers from the competition for available flying time. The above philosophy applies to Navigator and System Operator proficiency training as well as pilot training. Changes will similarly be required to permit accreditation of simulator time for Air Force Reserve officers in meeting annual flight requirements.

2. Career Motivation and Personnel Retention

Several institutionalized attitudes have had deleterious effects upon the retention and career progression of the most qualified training officers and airmen.

The problem results from a lack of recognition of the importance of providing positive career incentives for those working in the training field. The concept of the development of a cadre of highly skilled, motivated and properly rewarded officers and airmen is a concurrent necessity with the decision to emphasize synthetic training devices. The importance of qualified individuals in the Commands cannot be overemphasized. As the training programs become progressively more important in terms of overall Command proficiency and as the training media become more complex, there should be a commensurate upgrading of personnel rewards. Organic capability to perform modifications necessary for simulator update has been developed by the Commands. Project Pacer Flash Report, Volume IV, Appendix C "Air Crew Trainers" outlines the Quick Modification (QM) program instituted by the Commands to perform training simulator modifications, including design engineering, if required. The QM team in conjunction with AFLC take necessary actions to institute changes to the hardware and software as required to modify and improve system performance and expand training capabilities. The Pacer Flash, Volume IV Report has recommended expansion of the organic QM concept including the expansion of personnel resources available to the Commands. In addition, this report recommends that AFLC take an active role in the organic support of simulators by developing engineering capability to participate at the operational prototype centers in organic modifications. Ogden ALC/MM has prepared a plan to develop this capability. The Ogden plan has been approved at Hq AFLC. This expanded role of AFLC and formal recognition of the Commands' organic capability requires a high level commitment to training, motivation, progression, and retention of officers and airmen in this training simulator career.

3. Aircrew Member Acceptance

A common and probably false apprehension is the purported disinclination to simulator training on the part of aircrew members. For the most part, the reasons for such disinclinations when they do exist are experiences with inferior equipment or peer group pressures for large accumulation of flying time credit. To the extent that modern simulators represent fidelity and a true challenge to the aircrew member, a great part of the former problem will be alleviated. The latter problem is likely to yield only to time and a new way of life. Discernible change is already taking place as young and highly motivated officers with both operational and scientific backgrounds express real concern for the value of proficiency flying as it is conducted today in nonoperational assignments. There is little question in their minds that periodic training in a modern simulator truly representative of their cockpit job is vastly superior to current practices in nonrepresentative aircraft.

4. Maintenance of Interface Skills

A valid concern exists for the proper consideration of maintaining the skill level and motivation of personnel engaged in support and interface functions. As simulator time replaces actual aircraft flying time, the functions of aircraft maintenance, ground environment communications and control, emergency crew operation, etc., could stagnate and deteriorate from lack of exercise. Means will have to be sought to protect surge capability by continuation training for these interface functions. While this problem will be slow in materializing and may in fact, never develop, it is nevertheless, a valid concern as significant reductions in air time are achieved. Normal mission flying apart from training flying is quite different from Command to Command. Much of the flying in the Military Airlift Command is logged as revenue or mission time; however, peacetime flying in the Tactical Air Command and the Strategic Air Command is virtually 100% training with the exception of mission support operations. The MAC has voiced the concern that significant reductions from present mission flying will require either more flying training time or a corresponding upward revision to the quantity of simulators since considerable continuation training is now accomplished in conjunction with revenue flying.

5. Maintenance and Logistics

Project Pacer Flash, Volume IV "Air Crew Trainers" has made a number of recommendations for developing and accomplishing simulator software supportability including planning for personnel training, configuration management, support facilities, and organic (in-house Air Force) support capability. These recommendations are quoted in part below: (Reference 1)

"a. AFSC to:

(1) Plan and provision with ATC for training of Air Force personnel responsible to manage and implement software support after delivery of the simulator for operational use. These personnel must be trained to the

level of simulator system software engineers, technicians, programmers and computer operators. Skills required shall be identified for each simulator as determined by the subsystem functions included in that simulator.

- - - - " - - - -

(4) Establish procedures and assign specific responsibility to accomplish configuration management of simulator software.

- - - - " - - - -

(7) Define Air Force intent to accomplish some level of organic support while retaining an option for contractor development."

- - - - " - - - -

"b. Using Commands to:

(1) Designate and establish a support facility, i.e., a prototype site which, for the simulator, would be one of the operational simulators augmented with software support programs and peripheral devices. This single support center would provide configuration control inputs, implementation and verification/validation of all software changes."

- - - - " - - - -

"c. AFLC to:

(1) Manage software support as integral to the management of total simulator support.

(2) Develop skills and staff to accomplish support of simulator software and to manage acquisition of modifications, including software, which are beyond organic capability."

- - - - " - - - -

(5) Develop an engineering capability to provide assistance to the operation prototype centers in organic software modifications."

Ogden Air Logistics Center is responsible for the support of crew training devices including aircraft simulators. In accordance with AFLCM 66-18, Ogden is charged with configuration control of aircraft simulators. One of the recommendations of Pacer Flash (Item b.) envisions the inauguration of a system of jointly manned support centers for simulator software configuration management. A single support center would exist for each major simulator type which has dispersed application. While these recommendations concentrated on simulator software management and supportability, the growth in complexity in simulators per se will require changes to the manner in which maintenance is provided and managed for hardware as well. Total configuration management at these sites will be required. There is a need for strengthening the support provided by AFLC to maintain currency of simulators with the aircraft systems they represent.

6. Cost Estimating and Data Collection

A cost data base collection system for simulators is required if life cycle cost estimates are to have any basis in fact. Considerable progress has been made in tracking engine costs and other air vehicle related costs; however, the data base for simulator cost estimation is virtually nonexistent. In addition to the collection of a data base, cost estimating relationships must be developed to permit the prediction of new device costs for improving the utility of economic analysis decision criteria. A parallel effort should be undertaken to standardize the cost benefit considerations to be included when applying economic decision techniques for analyzing alternative choices. Direct and indirect operating costs associated with simulator facilities need to be recorded and relevant cost savings accruing to reduced aircraft operation and/or procurement identified. These should be realistic cost savings which are truly accountable to simulator usage and used for alternative decision problems. Since most of the capital investments are spread over a number of near term years and the returns likely to extend for a 10 to 15 year horizon from the initial investment, sensitivity to force structure decisions needs to be considered. The uncertainty of future force composition compounds the problem of quantifying future returns made difficult enough by uncertainties in the economy itself. A study to develop sound models for cost benefit analysis of simulator capital investment decisions is very much in order.

7. Industrial Base Expansion

The requirements for new and modified simulators for the Air Force represent in themselves a potentially untenable load for the vendors possessing the greatest competence. Furthermore, the other Services will be competing for the same sources since considerable similarity in technological needs exists among the Services. One obvious solution is to increase the industrial base to accommodate the demand; however, a great deal of investment by a company must accompany the decision to enter this field. It will do so if convinced there is a growing market with reasonable promise of stability in the future. It seems logical, therefore, that there be a deliberate program to expand the field of competence for simulator design and production to interested contractors. This decision by the Air Force and other Service elements needs to have behind it a dedication to continue in this direction regardless of the continuance or relief of energy shortages. Future procurements, if done on a piecemeal basis with no apparent continuity of purpose, will not likely attract new sources. It is conceivable that some procurement regulations and procedures might require waiver to broaden industrial participation in this field in order to build a larger competitive base for the future.

8. Inter-Command Coordination

A prime utility of the effort to develop a Master Plan has been the opportunity for an inter-command dialogue on needs, problems and approaches to solution. A common technology base coupled with an awareness of their common training mission exists as a basis for a useful dialogue among the Major Air Commands. A continuation of this dialogue including representatives of the Air Staff would be a useful forum for the exchange of ideas and airing of problems. The common need for greater emphasis on human resources research was one definitive result of such communication. Many of the institutional changes required to support the magnitude of the programs discussed were also voiced in these meetings. As a part of a continuing effort to improve communications, a number of steps have been taken to establish focal points and coordination groups. These are discussed under Management Initiatives in Section IV.

B. TECHNOLOGY ISSUES

1. Standardization and Commonality

As simulators become individually more expensive, the notion of standardization appears an attractive means to reduce duplication of effort and life cycle costs of equipment through simplification of maintenance and logistics operations. Standardization of pilot training simulators at the systems level is generally not possible because of the individualistic nature of each simulator for training in different aircraft. Standardization at the major subsystem level; viz., motion and force generation system, visual system, computer, instructor/operator station, etc., may be possible, but carries concomitant difficulties. At this time standardization of the motion system appears one of the more likely possibilities; a six-post motion system with specified stroke requirements would satisfy many common requirements of the Commands. As noted earlier in this document, several advanced development programs are now in progress to assess motion system parameters. A decision to standardize around a given concept will be possible with greater confidence at the conclusion of this research in 1976. Engineering judgment at this time favors the six-post, six degree of freedom synergistic system for application to simulators which will employ visual displays with wide fields of view such as used for fighter type pilot training. A three degree of freedom motion system would probably be sufficient for bomber and transport simulators which use visual systems with narrower fields of view. Annex C discusses an examination of the potential cost benefits and some of the difficulties attendant to the concept of a common motion base for a number of simulators now in the early phases of acquisition.

Visual system standardization is premature and the selection of a single type of system will in all likelihood not be possible for the foreseeable future. The reason for this lies in the complementary nature of the several types of systems now in use and in development, and the limitations of each to singularly satisfy a full spectrum of applications. As discussed earlier in Section II, image generation by model board with optical pickup and television processing fulfills a number of requirements which need high resolution, but do not demand variation in gaming area or wide field of view (i.e., greater than 140°). Film techniques are admirably applicable to requirements which require limited variation from a prescribed normal flight path and limited attitudinal variations; it would not be useful for aerial combat simulation for example. Computer generated imagery is in its infancy and has state-of-the-art processor speed limitations which limit its application to those predominantly involving cultural scene imagery as opposed to natural terrain variation with simultaneous demands for good to high resolution. The trend in visual system planning, therefore, is in the direction of eclectic systems, combining the features of the various types to suit the particular demands of the simulation task. To some extent, a degree of commonality can be envisioned to develop as a modular design approach is applied and as individual modules are developed for application to a variety of systems.

As discussed in Section II, computer commonality and standardization is being addressed with several interrelated tasks looking at both computer equipment and computer program (software) systems. The development of a computer selection model, to translate simulator performance and support requirements into computer system definition requirements through quantitative relationships, has been completed through the first phase. This model will now be refined to reflect the growing emphasis of software development and life cycle support costs. In particular, the impact of high-order language will be integrated into this model. The model will be used as a requirements definition tool.

Rigid standardization of computer equipment (hardware) is not necessarily the most cost-effective approach to achieve commonality in the computational system. Computer equipment technology has experienced an unusually rapid and significant increase in terms of the performance/cost ratio. Most recently the advent of the megamini computer has made real-time FORTRAN an economic reality for the simulation application. It is possible that standardization of the programming language requirements may be the most effective method to achieve commonality among different simulator applications.

The concept of directly incorporating the on-board avionics operational flight program (OFP) into the simulator is related to computer system commonality and standardization issues. Use of the OFP in the simulator is intuitively appealing in its apparent simplification of the requirement to update the simulator to current flight performance. On the more considered level, however, the concept demands a more rigorous and comprehensive level of simulation of the avionics driver environment to more exactly duplicate the real world system. In addition, this approach levies restrictions and limitations on instructional control and flexibility. It also demands maintenance equipment and personnel to service the on-board computer. The area of computational systems standardization or more realistically, increased commonality, is being pursued through engineering analyses and development activities. This includes analysis of software/hardware trades and compiler versus assembly language programming choices.

Simulators for aircrew training have much in common with simulators used for engineering and research into aeronautical system design. Philosophically, they differ mainly in their purpose. The simulator for design purposes demands great flexibility in terms of changing the aerodynamic responses of the simulator in accordance with variations in design parameters. The focus is mainly on the machine; however, there is complete recognition of the human element as he interacts with the machine. The training simulator generally has little demand for changing the machine characteristics, but rather needs wide flexibility in terms of the situation variables to be experienced in all phases of a mission. There is, therefore, a vast difference in software and, of course, in the instructor/operator station hardware. The hardware associated with the motion and force generation systems will differ to the extent the range of dynamic responses needed for the engineering simulator exceed those of the training simulator. A common technology base does exist for both type simulators and the extent to which each can contribute to the other needs to be examined and exploited.

2. Training Transfer

One of the most significant planning uncertainties is the degree to which training on a simulator can be substituted for actual aircraft flying training time. This uncertainty impacts not only predictions regarding reduced training loads on aircraft, but also on the number of simulators procured to offset the planned flight reductions. (Current programs which will be used to quantify data applicable to training transfer, and thereby minimize uncertainty are discussed in paragraph II.D.2.h.(3)). There exists two levels of uncertainty; namely, the applicability of a simulator to prepare a crew member for the performance of a given task in the aircraft and the amount of time required in the air vehicle to confirm simulator training, given that it is applicable. The former uncertainty is more clearly at issue in military training than in airline training because of the much more complex mission tasks associated with the military function. The Military Airlift Command, with the exception of certain specialized tasks such as air refueling, airdrop and air rescue, more closely parallels the airline experience than does TAC, ADC or SAC. The Air Training Command represents a unique problem in that it is involved in teaching basic skills to non-pilots as a part of its mission.

In a paper at the Second Flight Simulation Symposium, 16-17 May 1973 (Reference 2), Captain William L. Thomas, Director of Flight Operations Training, United Air Lines noted that" . . . simulator time increases about twice as fast as airplane time decreases." To what extent this experience is indicative of military substitutability is pure conjecture. It is clearly impossible to predict with any confidence how much simulator time will be required to ensure a level of proficiency equivalent to a given amount of flying time at this stage of our knowledge on advanced simulators. Much of the uncertainty is associated with the fact that a great deal of variability is dependent upon the instructor, simulator fidelity, and the training strategy employed. This too is derived from airline experience as well as military experience with ISD teams. Training transfer is then viewed as a phenomenon which must be addressed on several levels:

a. <u>On the research level</u>: To determine the relationships between simulator system fidelity and the cognitive processes; and the relationship of training strategies to improved efficiency.

b. <u>On the operational level</u>: By the introduction of equipments into the syllabus in a deliberate manner using the principle of Instructional Systems Development.

It is therefore important to treat the predictions of flying hour reductions with the caution they deserve since they represent real uncertainties which can only be resolved by reasoned measures as pragmatic experience is gained if a loss of force effectiveness is to be avoided.

3. <u>Over-Sophistication</u>

A great deal of judgment is required in answering the question, "if it <u>can</u> be simulated, <u>should</u> it be simulated?" Because of the uncertainties discussed previously regarding training transfer and simulator fidelity, there is a natural tendency to err on the side of overcomplexity in stating requirements. Stated another way, requirements tend to reduce as explicit usage is defined through ISD processes and as research provides a better understanding of mandatory cues and instructional features for specific task learning. The previously cited reference by the Director of Flight Operations Training, United Air Lines notes that their recent simulators have the capability of storing up to 1200 malfunctions of which only 318 have been programmed and only 60 used for the 747 simulator curriculum for pilots. Some additional ones are used for flight engineer training but a great number have never been used in any training program. Similarly, 90% of their simulator training in using radio aids in large metropolitan areas is accomplished using the San Francisco area, yet six others have been programmed and are available.

The issue is a difficult one in that requirements and indeed specifications are needed long before ISD initial validation is completed and, as in the present case, before research into fundamental simulator training transfer studies are complete. It will be required to seek alternative solutions and debate their merits and costs, including maintenance and logistics aspects, on a case-by-case basis. When flexibility can be provided to permit growth to hedge against real uncertainties at moderate cost, this in general is a cost-effective solution. Caution is mandatory in providing marginal gains at extreme costs when alternatives, including flying, exist. Project "ACE" is excellent guidance in the avoidance of over-sophistication and the principle of examining life cycle cost impact on each decision is required to realize the potential of simulators as an economic training medium.

4. Productivity Improvements

Another important factor in the realization of the full potentialities of simulators is a qualitative improvement in reliability and maintainability. The new dimension of visual simulation while providing a real breakthrough in terms of increasing the applicability of simulators to training tasks heretofore relegated to actual flight, adds a significant additional challenge to achieving good productivity.

The more complex instructor/operator stations at once offer increased productivity and increased chance for failure. Every additional complexity has its *quid pro quo* in being subject to failure and repair.

One can define a productivity ratio (PR) as a mathematical expression relating simulator training to equivalent training in an aircraft:

$$PR = \frac{\text{Sim. Utilization Rate (hrs/yr)}}{\text{Aircraft Utilization Rate (hrs/yr)}} \times \frac{1}{\text{Trng Transfer Ratio}}$$

where: the training transfer ratio is defined as the number of hours in a simulator divided by the number of hours in an aircraft for equivalent training.

Simulator utilization rate experience has been variable in the Air Force. The Military Airlift Command experience indicates that 16 hours per day for modern devices is the highest which can be attained without significant deterioration of equipment and maintenance capability. A number of factors influence the productivity ratio by operating on various parts of the equation. The maximum simulator utilization rate is directly a function of the mean-time-between-failures (MTBF) and the mean-down-time (MDT). The MDT is a strong function of the time available for "hands on equipment" training afforded the maintenance personnel. Without such training, the MDT can increase beyond tolerance.

$$\text{Max. U.R.} = \frac{\text{MTBF}}{\text{MTBF} + \text{MDT}}$$

The MTBF factor is in turn a function of the type and number of components in use, the duty cycle, the operating stress levels encountered, the operating environment and the equipment configuration (Reference 3). The MDT includes the time for repair plus administration, waiting and logistic time. It is obvious that these two factors are not only functions of the design, but of the operating, maintenance and logistics policies and organizations as well.

High utilization rate requires real concern for the manner in which systems are designed and how they are designed for repair. The Integrated Logistics Support

(ILS) concept expressed in DoD Directive 4100.35 appears ideally suited to relatively large simulator programs. This concept is further defined in AFLCM 800-1, AFR 800-8, AFP 800-7, and DoD 4100.35-G, Integrated Logistics Support Planning Guide for DoD Systems and Equipment. The concept requires the introduction of logistics consideration in planning documents beginning with the ROC and the development of an initial Integrated Logistics Support Plan by AFLC. The principles of ILS are well recognized; however, there has been widespread failure to implement the concepts even on major systems. Unless real attention is given to this by everyone in the chain of action from Major Command preparation of the ROC to AFSC/AFLC coordination in the acquisition and operational phases, the principles will remain valid, but the product will remain inadequate.

The above actions can do much to assure minimal downtime given a failure; several other factors relate to high productivity.

a. Graceful Degradation

The system design concept should strive for failures to permit continued operation of at least part of the system while maintenance is being performed. The software programs developed with the hardware should be constructed to permit operation in likely failure modes to maximize residual capability.

b. Modular Design

The system design concept should stress modular design with line replaceable units. Duplication of failure sensitive elements (i.e., likely to fail and/or the impact of failure is grossly incapacitating) would probably be cost-effective in the long run and should be identified early in the design phase.

c. Development of Total Training Strategy

AFHRL research should continue to expand the notion of developing total training strategies by close association with the Major Command ISD teams. Colocated AFHRL personnel should be assigned to training program development teams for implementing and optimizing syllabi when new and complex training media are introduced.

SECTION IV

MANAGEMENT

- - - The overall management of simulators was excellent at base level, and facilities were adequate. However, problems were found in the areas of logistics and personnel support, configuration control, and guidance for simulator utilization. These conditions have prevented the Air Force from obtaining the maximum simulator training benefit at the least cost.

Air Force Audit Agency
Summary Report of Audit
Flight Simulator Utilization
and Configuration Control
18 September 1974

A. INTRODUCTION

In the year following the publication of the initial Air Force Master Plan - Simulators for Aircrew Training, there has been significant evidence that the Air Force has followed the recommendation contained in the 1973 USAF Scientific Advisory Board Report of the Ad Hoc Committee on Air Force Simulation Needs. This report recommended that - - - "The management structure for flight simulation within the Air Force be realigned and strengthened to support the extended use of simulation throughout the Air Force."

While significant decisions in the management area have been made, time will be required for the impact of these decisions to be felt at the operating level. It is the purpose of this section to review the progress that has been made in aligning the Air Force management structure to accommodate the vastly increased emphasis on simulation and to consider the problems which will continue to demand new management initiatives.

B. BACKGROUND

Flight simulators can be broadly categorized in terms of their end use for either flight crew member training or engineering/human factors evaluation. In the latter category, simulators are developed and operated by elements of AFSC for investigation of such matters as flight instrument display and layout, aircraft design performance comparisons, stability and control criteria, etc. Such machines certainly share some of the requirements of and benefit from improvements in flight simulators of any type, but are sufficiently unique in their design and operation that they must be distinguished from machines intended for use as training devices. This Master Plan is concerned solely with synthetic training devices; thus, this section will deal with matters entirely in the context of devices intended for use in training.

Historically, the development of flight training simulators has been carried on by each individual System Program Office (SPO) as a part of the supporting equipment for the weapon system. The thread of continuity in design and operating features from system to system was largely provided through a common source of engineering support, specifically the Simulators and Human Factors Division (ASD/ENCT), Directorate of Crew and AGE Engineering of the Deputy for Engineering. Although the potential for expanded use of simulators in training has been recognized for many years, the demands for single-minded dedication to getting the development of the actual weapon system completed within tight, and many times volatile, fiscal constraints resulted in at best sporadic availability of resources from the SPOs to pursue technological advances for simulators. Nevertheless, over the years, simulators gradually improved from the early AC analog machines, that can hardly be regarded as "simulators", to the digitally driven machines with limited motion and visual display capabilities in use today. Understandably, the result has been the introduction of marginal equipment in some cases, and a lack of commonality or even a sense of orderly progression that has made maintenance and updating difficult and expensive and given simulators in general a rather tarnished image among operational personnel. Until recently, this general posture was allowed to continue because the Air Force was relatively unconstrained in conduct of required training through operation of the actual aircraft weapon systems. In contrast, absolute necessity brought the development and use of simulators to a high degree of sophistication in the NASA Apollo program. Economic forces, notably similar to those now impinging on Air Force flight operations, also brought about extensive use of flight training simulators by the commercial airlines.

Rapidly increasing complexity and operating costs of new aircraft weapon systems brought about a recognition of the need for consolidation of activities associated with the acquisition of simulator systems at the Aeronautical Systems Division. To this end, the Simulator System Program Office (ASD/SMS) was created within the Deputy for Subsystems in May 1973. This Simulator SPO is charged with the management of assigned aircraft mission simulator and training device programs, including electronic warfare trainers, aircrew training simulators, instrument flight simulators, and prototype simulators for evaluation of new techniques and technology. The SPO also interfaces and coordinates with other DoD and government agencies to provide a central point for Air Force simulator and training device technology and information.

C. MANAGEMENT INITIATIVES

A number of reports by governmental agencies, including the Office of Management & Budget, the general Accounting Office, the USAF Audit Agency and most recently the USAF Office of the Inspector General, have cited deficiencies in management and use of flight simulators.

1. Policy and Institutional Changes

The studies noted above expressed concern for certain institutional impediments to the economic realization of the full potential offered by advanced simulator technology. These areas relate by and large to the Planning Issues discussed in the previous section and include Command and aircrew member acceptance and endorsement of the extensive and extended use of synthetic training devices. A subelement of this general acceptance is the requirement for regulatory changes to AFR 60-1 to permit credit for simulator training toward the fulfillment of annual proficiency training requirements. A change to AFR 60-1 to permit such accreditation is scheduled for April 1976.

Acceptance of the premise that simulation can reduce flying training is a concomitant of the general policy of increased emphasis and reliance upon simulators to provide significant portions of transition and proficiency training requirements for aircrews. That the Air Force has accepted this premise is evidenced by the statement by the Chief of Staff of the Air Force that "- - - Air Force policy is to strive for a 25 percent reduction in flying hours by the end of FY 81 through the increased use of simulation. While operating cost and energy considerations are the driving factors, other reasons such as restricted airspace, environmental ecological impacts, safety and aircraft attrition are also major considerations. - - -"[1]

A number of organizational changes have been directed, and focal points and coordinating groups established to implement the policies enunciated by the Chief of Staff:

- Brigadier General Norman C. Gaddis (USAF/XOO) was designated as Special Assistant for Aircrew Flight Simulator Matters. As part of his responsibility, General Gaddis provides quarterly briefings to the Secretary of the Air Force in conjunction with Program Review meetings. The purpose of the quarterly briefing is to advise, recommend, and to enable the Secretary to review the entire Air Force simulator program from a common base. These briefings are in addition to the

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[1] CSAF message 252107Z April 1975.

Operational Flight Programs, Major H. C. Falk, ASD/ENAIA; Crew Training Simulators, Mr. P. S. Babel, ASD/ENCTS; and Automatic Test Equipment, Mr. R. C. Behymer, ASD/ENCEE.

● A Simulator Advisory Group (SAG) was established by direction of the Commander AFSC and a Charter was approved by the ASD Vice Commander in May of 1975. The functions of the group will include:

a. Periodically review Air Force aircrew simulator programs for effectiveness and efficiency and to promote timely definition and integration of research, technology, engineering, acquisition, and logistic support.

b. Provide a focal point within the Air Force for maintaining a continuing interface with the Navy and other organizations involved in simulation technology and hardware development. The purpose of this activity will be to ensure an aggressive and timely interchange of information on technology, acquisition programs, operational experience, and methods and procedures for simulator development, acquisition and support.

Membership of the SAG includes representatives from Air Force Systems Command, Air Force Logistics Command, and the Major Operating Commands. The Group is chaired by the Deputy for Subsystems at the Aeronautical Systems Division. An initial task of the SAG was to visit Naval Training Equipment Center (NTEC) in March 1975 to examine that organization to determine what features should be considered for incorporation into AF organization and management structure for simulators and training equipment.

● A Business Strategy Panel for simulators was established in August 1975 at the Aeronautical Systems Division. The purpose of the Panel is to provide the corporate memory of ASD to Program Directors in the form of guidance and advice as they structure and implement their program.

● An exchange of liaison officers was effected between the NTEC and the Simulator SPO (ASD/SMS) at ASD. This exchange will provide resident liaison officers to assist the flow of information between the Navy and the Air Force at the research and development/acquisition agency level.

quarterly system program reviews which include the respective weapon system simulator.

● A single focal point for simulator matters was established within Hq AFSC under the Deputy Chief of Staff for Systems; Colonel C. R. Linton, Director of Operational Support Systems (AFSC/SDA) was assigned this responsibility. Additionally, a new Aircrew Simulator Devices Division (AFSC/SDAS) was established to provide a headquarters AFSC office of responsibility for simulators for both inventory aircraft and those under development. The new Division is headed by Lt Col R. Lacey. The Office is responsible for cognizance of all AFSC simulator activities including: technology efforts and all weapon system simulators; implementation of programs directed to AFSC for development and procurement of aircrew flight simulators for aircraft transferred to AFLC; AFSC management of PE 64227 "Flight Simulator Development"; review of all aircrew flight simulator ROCs; and interface with other USAF agencies in the aircrew flight simulator area.

● AFSC/DL designated the Air Force Human Resources Laboratory (AFHRL) to be focal point laboratory for the development of training simulator technology. The Air Force Avionics Laboratory (AFAL) and the Air Force Flight Dynamics Laboratory (AFFDL) were designated as participating laboratories. AFHRL is responsible for:

a. Maintaining awareness of all significant R&D being conducted in other Air Force laboratories, other DoD organizations, NASA, and industry IR&D programs,

b. Making recommendations concerning work assignments, elimination of redundancy, changes in emphasis and required resources, and

c. Annual preparation of an overview concerning all Air Force training and training related simulation technology.

● An ASD management focal point for weapon system software has been established at the Aeronautical Systems Division within the Avionics Standardization Office. (Mr. C. Paul Johnson, ASD/RWSV). Three software technical area focal points will support this management focal point:

- In April of 1975, Hq USAF directed AFTEC (Air Force Test and Evaluation Center) to assume the responsibility for managing the IOT&E of simulator programs qualifying as "Major Systems" within the criteria defined by DoD Directive 5000.1 as well as the IOT&E of simulator programs identified by program element of Major Weapon Systems. AFTEC is to monitor the IOT&E of "Non-Major" simulator programs. Specifically, AFTEC will manage the IOT&E for the B-52 and KC-135 Instructional Systems; it will provide monitorship for the C-130 Simulators, UNT-T-45 Simulator, UPT Instrument Flight Simulator, H-3/HH-53 Helicoptor (Visual), the Simulator for Air-to-Air Combat, B-52/KC-135 Aerial Refueling Part Task Trainer, and the Digital Radar Land Mass Simulator, and F-15 Simulator.

- An item submitted by NASA at the 13 August 1974 AFSC/NASA Aeronautics Technology Meeting resulted in a survey by the Air Force Flight Dynamics Laboratory (AFFDL) to ascertain the level of interest in establishing a NASA/DoD Simulation Coordination Group. This Group would provide a formal means of exchanging technical flight simulation information and foster working level coordination and cooperation in simulation research and development activities between the US Government Agencies in general, and AFSC/NASA in particular. The work of the Group would cover technology for engineering simulation as well as training simulation. While the results of the survey of interest were in general favorable, questions of scope and structure have yet to be worked out. Efforts are continuing to determine the best forum for achieving interagency coordination in this fast moving technology area.

2. Operating Level Changes

A management decision which will have considerable impact at the operating level is the transferral of the flight crew simulator maintenance function from operations to logistics. In April of 1975, this change was directed by the Air Force Chief of Staff to " - - - more closely align maintenance and support responsibilities at all levels. - - - (and to) ease the transition to the next generation of simulators and make the organization for simulator maintenance consistent with existing Air Force policy for weapon systems." A target date for this change to be in effect is 31 December 1975.

As noted in the quote from the Air Force Audit Agency Report at the beginning of this Section, items of principal concern at the operating level are the control of the quality of the maintenance skill training and career progression, configuration management of simulators, and the systematic planning for equipment use and scheduled maintenance. A number of the findings and management responses to these findings are summarized below:

- Finding

  There is a lack of uniform management guidance in the operating area including priority of simulator use, requirements for simulator instructors and operators, computer program control, and simulator scheduling.

  - Management Response

    AF Regulation 50-48 "Management of Training Equipment" will be expanded to include additional MAJCOM and USAF management guidance and responsibilities. This revision is expected to be completed by the third quarter of FY 76.

- Finding

  A systematic procedure for estimating costs of simulator operations did not exist.

  - Management Response

    Hq USAF/ACM and XOO are working with the MAJCOMs to develop a methodology for estimating operating costs. When complete, the methodology will be incorporated into a reporting directive. The question of operation and maintenance costs was addressed in a study accomplished by Ogden Air Logistics Center, Hill AFB, Utah. This study was initiated at the request of Hq USAF and performed at the direction of AFLC/MM. The report corroborated the Audit Agency finding that there are no cost/budget accounts established or procedures in-being which require the recording or projection of costs associated with the logistics support of specific training devices.

The Ogden ALC report[1] recommended that: "Training devices should be established and managed as a separate, major logistics category and assigned a separate Budget Program Code in each applicable appropriation for acquisition. System Management Codes should be assigned for each training device and used in the BPAC to account for expenditures from central procurement appropriations and Stock Funds. Standard cost accounts should be established to record the costs financed by Research and Development, Military Pay and Allowances, Operation and Maintenance, and Military Construction appropriations and Industrial Funds. - -"

- Finding

  There are significant differences between simulator maintenance job descriptions in AFM 39-1 and the work actually performed by console operators and maintenance personnel. Job descriptions are out of date with regard to the recognition of digital equipment.

  - Management Response

    The MAJCOMs have been tasked to develop new Air Force manpower standards for synthetic trainers. A Management Engineering Team (MET) will direct the development of uniform standards and ensure their continued currency. An occupational survey of AFSC's 342X0/343X0 was completed in April 1974 and briefed in June 1974 to the Multi-Command Simulator Conference held at Chanute AFB, Illinois. Revision to the AFSC structure was recommended and will require MAJCOM concurrence and updating of the new specialties in the simulator maintenance career fields. A target date was set for the end of CY 75 for review of the classification structure and overhaul of the maintenance training program.

- Finding

  The Air Force logistics system was unable to adequately support simulators. Due to the small

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1 Report by Ogden Logistics Center/MMR on "Cost of Government Maintenance of Training Devices."

number of requests for simulator parts, stock levels were low and many requisitions were back ordered. - - -

- Management Response

  Hq USAF tasked Hq AFLC to examine possible alternatives to the standard base supply system to determine if any changes could be made to improve logistic support of simulator operations. The Ogden ALC study noted previously, examined alternative methods of providing maintenance and logistic support including contract support of OIM (Organizational and Intermediate Level Maintenance). The report made recommendations which are under review at this time.

D. CURRENT SITUATION

1. Technology Area

There has been recognition of the need for a solid technology research and development program to support the policy of increased usage and reliance upon simulators for aircrew training. As noted in the previous Section, AFHRL has been designated as the focal point laboratory for simulator technology. A program has been developed by AFHRL, ASD/ENCT and ASD/SMS to be responsive to the current and future needs of the Major Operating Commands. This program is detailed in Section II.D of this document and covers exploratory development (PE 62703F "Human Resources"), advanced development (PE 63102F "Innovations in Training and Education" and PE 63719F "Simulator for Air-to-Air Combat"), and engineering development (PE 64708F "Other Operational Equipment" and PE 64227F "Flight Simulator Development". An annual update of this technology program plan has been directed by the Commander of AFSC. The complicated fiscal structure is the result of many factors, but mostly the result of a prior lack of priority to develop and fund a coherent program of research and development within the classic laboratory funding structure. The danger in the complex structure is one of maintaining technological coherence within a noncoherent fiscal structure. Efforts to assure adequate funding in each of the program elements must succeed in order for the technology program to succeed.

Management attention will be required to impact the fiscal structure to assure a continuity of funds. As noted in Section II.D, the advanced development budget for FY 76 is approximately half of that required. Most of the funding requirements shown in that Section represent new starts to catch up with the needs of the Commands.

2. <u>Organization Roles</u>

A strong, cohesive management structure for all aspects of flight training simulators and other synthetic training devices would derive best from clearly defined roles and responsibilities for all the participating organizations. Clear organizational roles will facilitate orderly initiation of projects, provide clearly understood support responsibility, supportable funding and manpower requests, responsive and responsible communications among user, developer, and approval authorities, and the avoidance of conflicts arising from poorly or purposefully misunderstood mission responsibilities. The initiatives discussed previously have gone far in accomplishing this redefinition.

The management concept for simulator acquisition and support to meet MAJCOM requirements is based upon three organizations in key roles, with support from several others in their particular areas of expertise. Stated in general terms, these key organizations and roles are: AFHRL, which would provide the technological foundation for training devices, in both equipment and human terms; Simulator SPO (ASD/SMS), which would manage programs in validation, full-scale development, and production phases; and, AFLC, currently the Ogden Air Logistics Center, which would maintain the configuration of training devices compatible with the associated aircraft and provide logistics support for devices maintained by government personnel. Each of the three would also be expected to operate as a central point within its indicated area of activity for continuing liaison with other government agencies (e.g., Navy, Army, NASA, FAA, etc.), airlines, industry, and the ultimate users within the operating commands of the Air Force.

As the key organization in the technology efforts on training devices, AFHRL is the action organization for the 6.2 and designated 6.3 programs described and listed in Section II. An important ingredient in performance of those programs would be the level of participation and assistance rendered by AFFDL, AFAL, and AMRL. Provision should be made for informal but regular and systematic review by those organizations of plans and progress on the AFHRL simulator programs as a means to exploit their unique position as developers of complementary technology and users of simulators in their own right. The designation of AFAL and AFFDL as participants in support of AFHRL was done in full recognition of the distinction existing in the association these laboratories have vis-a-vis simulators. Their involvements are primarily in the role of users of simulators to support engineering design and evaluation of weapon systems and related technologies. The resulting expertise, however, does represent a resource that can be profitably applied to the design evaluation, and operation of simulators for training purposes. Plans are discussed in Section II relative to the use of the LAMARS (Large Amplitude Multi-Mode Aerospace Research Simulator) at AFFDL for evaluation of air-to-ground visual display options. The Aerospace Medical Research Laboratory (AMRL) will also be a valuable resource for assistance to AFHRL in developing and conducting an effective R&D program.

The Simulator SPO (ASD/SMS) functions as a central program management organization for engineering development, production, test, and deployment of simulators and other instructional devices for all operational Air Force aeronautical weapon systems and functions as the simulator acquisition management agent for new weapon system developments when assigned that role by the ASD Commander. In addition to management of the acquisition of synthetic training devices in direct support of new weapon systems, activities involved would include: management of prototype technology integration programs; maintaining awareness of operational command experience with equipment; providing guidance to technology programs; assisting operational commands in development of requirements that realistically account for the state-of-the-art in simulation; and carrying on active interface with other agencies using and/or developing simulators (e.g., Navy, Army, NASA, airlines).

The Simulators and Human Factors Division (ASD/ENCT) has historically functioned in the role of engineering support for the engineering development and production activities on simulators through colocated personnel in the various weapon system program offices. It is the point where all engineering aspects of simulator technology are integrated for comprehensive support of all Engineering Development and Production programs carried on by ASD/SMS. Fulfillment of that role would seem to require gradual withdrawal of ENCT personnel colocated with weapon system

SPOs as simulator projects are completed or transferred to SMS, and ultimate total dedication of the aircrew training simulator personnel of ENCT to support of SMS activities. The comprehensiveness of that support suggests a need for review for the future of the skills present in ENCT for possible augmentation.

A further major area of support for the Simulator SPO is that of advance planning, the assigned mission of the Deputy for Development Planning (ASD/XR). It is envisioned that ASD/XR would carry on advance planning for training simulators as a part of a continuing, overall examination of the training equipment needs for advanced aeronautical weapon systems. As advanced systems concepts move from the Conceptual Phase toward full-scale development and a SPO Cadre is formed within ASD/XR, the requirements for and funding of training devices should be a matter of specific attention and should include participation by personnel from ASD/SMS and ENCT. This arrangement would provide for the incorporation of ASD/XR's planning into the definitive planning/programming of the SPO Cadre and early involvement of the organizations (SMS and ENCT) that will subsequently carry on the development/production of the training equipment involved.

Finally, AFLC would be responsible for maintaining the physical and functional configuration of simulators and other training devices current with the operational system to which they relate. Also, the responsible Air Logistics Center would work closely with ASD/SMS and AFHRL in maintaining active feedback of data and information on operating experience with equipments in the field.

The management concept suggested above and expressed in terms of roles and responsibilities for organizations involved in the conception and realization of simulation and training devices would require minimal restructuring of existing organizational functional statements, but does call for examination of the skills and human resources available within the organizations involved and the nature of activities in which they are or should be engaged.

3. Programming Structure

Another ingredient necessary to strong management is a fiscal structure that can be controlled, yet is responsive. It is important to develop a coherent fiscal structure for simulators. Simulator funding has been difficult to identify, and consequently, funding requests become confused by the complexity of the structure itself. Engineering development and production of simulators for new weapon systems are funded as a part of the budget authorization to the weapon system SPO. As noted in Senate Armed Services Committee Report 93-385, future procurement requests should specifically identify aircraft simulators on the same basis as the aircraft they are designed to support. The major dollar requirements identified in this Plan relate to new equipments for operational aeronautical systems. As such, funds will be required in the 3010, 3080, and 3600 appropriation areas and will be associated with Program Elements supporting the operational commands. Research and Development to provide a technology base for new procurements will require funds in the 6.2 and 6.3 Program Element areas. Research and development funding for simulators has not had a great deal of coherence since development of new technology has been funded through several Program Elements as a matter of expediency. Consolidation of funding requirements within and augmentation of P.E. 62703F, Human Resources, together with specific highlighting of projects associated with aircrew training simulators within this Program Element appear to be minimum steps to clarify simulator exploratory development funding within the Air Force. Advanced development (P.E. 6.3) funding should be similarly augmented, and a coherent funding structure should be established for aircrew training simulators.

Any truly advanced technology development program should be undertaken by the Simulator SPO only if there is a high likelihood that the equipment involved will be eventually procured for operational command use. The SPO should not be called upon to manage programs that result in equipment intended to be used for research only. When an area of investigation has progressed to the point that a full-scale feasibility demonstration is the next logical step, the effort should be proposed and handled as a 6.3 Advanced Development Program in AFHRL, following the existing practices for review and authorization of such efforts.

INTRODUCTION TO COMMAND SECTIONS

The material contained in the sections to follow represents the results of the process outlined in Section I to identify Command needs and to translate these needs into action programs. Several significant points which should have been made clear in the immediately preceding sections are noted again for emphasis:

- Simulators have been and will continue to be an integral part of each Command's training program; they cannot replace actual flying training until they are fully integrated into the training syllabus in a deliberate and considered manner. This implies not only acquisition of equipment, but the acquisition of knowledge and confidence from the exploitation of advanced development programs now underway.

- A commitment by management at all echelons must be made to effect the transition to increased simulator usage by clarifying roles and missions, adopting permissive regulations for simulator substitution for credited flying training, and providing the organizational resources needed to support the systems procured.

- Synthetic training devices must have the following characteristics if they are to achieve effective and economical training:

    - High reliability and utilization rate,
    - Fidelity to the cockpit environment,
    - Expansion into the visual and sensor domains,
    - Improved instructional features, and
    - Proven training value.

OMB Staff Study of July 26, 1973 entitled "Department of Defense Aviation Program Savings Possibilities Through Increased Emphasis on Flight Training Simulation," outlined a goal oriented, phased reduction of flying hours. This study presented a flying hour reduction goal of 50% for UPT and conversion training, and 20% for operational training by FY 78. In general, the Major Commands have accepted the principle of such a goal oriented reduction of flying training. The time for achievement and the magnitude of any given level of reduction is paced by Command judgment and by realistic acquisition program schedules in association with scheduled exploitation of ongoing advanced development programs related thereto.

The program data should be looked upon as a planning overview of the totality of programs which collectively could move toward the specified goals of the individual commands. It is, of course, highly improbable that all of the financial needs of the Commands will be met in entirety; it is recognized that trades will eventually be made between performance requirements and financial capability. Individual program cost and schedule data are highly temporal; however, a total picture of all programs serves to outline and underline the scope of this undertaking.

The Commands have established a prioritized listing of the programs needed to accomplish their objectives. The optimum allocation of funds across Commands requires a good deal of subjective judgment to determine the optimization criteria. A number of criteria are possible and perhaps equally valid: the present emphasis on energy conservation, particularly as it applies to petroleum products suggests fuel savings is an important consideration; the magnitude of returns on investment in terms of dollar savings; the speed with which returns can be realized, either in fuel or dollar resources; the effectiveness of the training provided in reducing aircraft accidents; and, any "free assets" which might accrue to reduction of demand on the aircraft inventory to supply training missions. Annex B contains an analysis of the program data (cost estimates and schedules) combined with Command estimates of the impact of the simulators on their respective flying training programs.

In general, the quantities of simulators specified by the Commands include consideration of the anticipated training load for active force personnel and Air Force Reserve and Air National Guard personnel. At this time, the Commands are in the process of defining future training requirements for the USAFR and ANG which will necessitate revisions to the AFM 55 series manuals. Future editions of the Master Plan will identify the resource allocations planned for these organizations.

SECTION V

AIR TRAINING COMMAND (ATC)

A. GENERAL

The "Mission Analysis on Future Undergraduate Pilot Training" published early in 1972 was a comprehensive systems approach program which is being used by the Air Training Command to guide utilization and planning efforts in Undergraduate Pilot Training (UPT). Information from that study effort supplemented by additional planning and analysis formed the basis for the Command input to the Master Plan. Included is the role simulation equipment can play in upgrading and improving the efficiency of other ATC formal flying training courses; viz., Pilot Instructor Training (PIT), Undergraduate Navigator Training (UNT), Instrument Pilot Instructor School (IPIS), and Electronic Warfare Officer (EWO) training.

The Air Training Command recognizes the potentials of simulation in flight training programs, and plans for improved and more economical training through increased reliance on simulators. The programs outlined in this section are viewed as reasonable extensions to programs now in the acquisition phase which will form a plateau of capability over the next decade. Each increment of improvement is based upon the successful completion of associated advanced development programs and the careful integration of these capabilities into the training syllabus by application of ISD activities. As noted in other sections of this Plan, the estimates of flying hour reductions are predicated upon the substantiation of training transfer capability by hands-on experience. The reduction of the flying portion of the syllabus must be undertaken with care to avoid the transference of an undo burden on the receiving Commands where flying training would be accomplished at greater cost and greater risk.

The current and projected student load associated with the noted formal training programs is shown in Table V-1. The Table refers to entries to the programs with production rates for UPT as noted in the Table. Numbers of equipments required were based upon a theoretical production capability of 3000 for UPT, 1000 for PIT, 250 for IPIS, and 1500 for UNT. These same nominal loadings were used for

TABLE V-1

ATC STUDENT TRAINING RATES (ENTRIES[1])

	UPT T-37	UPT T-38	PIT[2] T-37	PIT[2] T-38	IPIS T-38	UNT[3] T-37/T-43
FY 1976	1579	1379	358	379	240	864
FY 1977	1388	1313	250	245	250	907
FY 1978	1413	1237	268	264	250	632
FY 1979	1615	1322	316	318	250	632

1. PRODUCTION RATE IS APPROXIMATELY 86% OF THE ENTRY RATE FOR T-37 AND 95% FOR T-38 UPT.
2. FOR PIT THE NUMBERS ARE MUTUALLY EXCLUSIVE.
3. PRODUCTION RATE IS APPROXIMATELY 88% OF THE ENTRY RATE.

REFERENCE: USAF FLYING TRAINING 77-3 (VOL I), MARCH 1975.

computations of fuel savings accruing to the substitution of simulators for flying hours in the projected training syllabi.

The Air Training Command currently is using the T-4/T-26 Flight Instrument Trainers in UPT/PIT. Table V-2 provides a summary of terms which will be used to describe the training equipment resources of the Command. The T-4/T26 Instrument Flight Trainers consist of the cockpit section of the training aircraft complete with consoles, panels, controls, ejection seats and windshield bar. Most instrumentation for aircraft systems as well as all engine systems and flight dynamics are operational and indications are generally representative of the aircraft and systems performance. These flight instrument trainers employ analog computers to achieve real time control response. No motion base nor visual system is employed. The system is able to simulate most normal and emergency procedures. The T-4/T-26 trainers are used as part task instrument trainers and procedures trainers. Aircraft instrument sorties are preflown in the trainer with skill in instrument procedures being derived from trainer exposure and practice. Familiarity and practice in normal and emergency procedures is also achieved in the trainer. Money spent on motion or visual systems would not be cost-effective since most of these trainers have exceeded their design lifetime.

The Instrument Pilot Instructor School curriculum contains only a modest amount of flying in relation to the total training program. There is an ongoing ISD effort to refine this program and examine the application of training media. "The plans for upgrading IPIS media resources discussed in this document must be considered 'best estimates' until media are addressed in the ISD program. Using Commands have indicated that any appreciable reduction in the flying hours associated with the present curriculum, even with the advent of high-fidelity simulation, may not be acceptable".

The Undergraduate Navigator Training (UNT) program has undergone vast changes during fiscal year 1975. The process of full integration of T-43/T-37 all jet flying and the partial integration of the T-45 ground simulator into the UNT program began with the entry of Class 76-03 on 2 January 1975 into the Undergraduate Navigator Training (UNT) program. Production and delivery delays in the T-45 procurement cycle necessitated continued or increased use of existing training devices and additional T-43 flight missions in the Modified

TABLE V-2

ATC TRAINING EQUIPMENT AND GLOSSARY OF TERMS

AIRCRAFT			TRAINER/SIMULATOR			
DESIGNATION	USE	STATUS	DESIGNATION	USE	STATUS	FEATURES
T-37	UPT, PIT & UNT	CURRENT USE	T-4	IFT	CURRENT USE	COCKPIT CONTROLS & DISPLAYS, NO MOTION NO VISUAL
			T-50*	IFS	IN PRODUCTION	MOTION + VISUAL WITH COCKPIT
T-38	UPT, PIT & IPIS	CURRENT USE	T-7/T-26	IFT	CURRENT USE	COCKPIT CONTROLS & DISPLAYS, NO MOTION, NO VISUAL
			T-51*	IFS	(SEE T-50)	
			T-40	IFT	CURRENT USE	
T-43	UNT	CURRENT USE	T-10	BOMB/NAV FOR B-52 G/H	CURRENT USE	
T-41	BASIC TRAINER	CURRENT USE				
			T-40	UNT	CURRENT USE	
			T-4	EWOT	CURRENT USE	
			T-5 (SENT)	EWOT	CURRENT USE	
			T-45	UNT	CURRENT USE	

* UPT-IFS

UNT = UNDERGRADUATE NAVIGATOR TRAINING

IFT = INSTRUMENT FLIGHT TRAINER

IFS = INSTRUMENT FLIGHT SIMULATOR

EWOT = ELECTRONIC WARFARE OFFICER TRAINING

UPT = UNDERGRADUATE PILOT TRAINING

PIT = PILOT INSTRUCTOR TRAINING

IPIS = INSTRUMENT PILOT INSTRUCTOR SCHOOL

Undergraduate Navigator Training (MUNT). The last class under MUNT will complete training on 26 May 1976. Table V-5B depicts the foregoing transition graphically. Significantly it must be noted that the full implementation of the T-43/T-37/T-45 UNT program has reduced total flying by 74.5 hours and reduced other training device time by 51 hours. Each student station of the T-45 ground simulator duplicates in form, fit and function the master student station of the T-43 aircraft. The T-45 has provisions for 52 student stations (13 complexes with four students, one instructor, and one operator per complex). The 13 complexes may be operated independently with a total of 52 different mission tracks in progress. Missions may be planned over the entire Northern hemisphere at speeds up to Mach 2.0 and altitudes to 70,000 feet. Radar coverage is limited to the Continental United States to a resolution of 250'. All radar data is stored in digital format along with all other mission data. The original milestone date for the first complex delivery was August 1973. Technical design problems and subsystem debugging during integration delivery delayed first complex delivery until December 1974. Delivery of the 13th complex is scheduled for February 1976. Each UNT student will receive 80 hours of T-45 training. Each student in the simulator acts as "lead" navigator at his station and has the capability to "fly" missions using any combination of navigation aids available. The simulator is also capable of portraying problems associated with long range, high and low speed missions outside the capability of the T-43.

Navigator/Bombardier Training (NBT) requires a new simulator to replace the T-10 simulators now in use. The simulators are ground-based replicas of the navigator/bombardier stations within the B-52G/H model aircraft and have been in continuous service over ten years. Though adequate for the current time frame, their usefulness is limited to training navigator/bombardier students for only the B-52. Simulator requirements for the future call for a new navigator/bombardier simulator in the NBT course. The course will be required to train navigator/bombardiers in the more advanced weapon systems such as the B-1 and advanced versions of the F-111 aircraft. This will necessitate a simulator more closely aligned to the current state-of-the-art in avionics than is possessed by the ASQ-38 T-10. There are no additional tradeoff possibilities for simulators in lieu of flying time since the NBT program is already a no fly course; however, research is required to meet some of the advanced system training needs of future USAF aircraft.

The Simulator for Electronic Warfare Training (SEWT) is a general task, computer controlled, electronic warfare simulator capable of simultaneous training and evaluation of eight students. Each student station includes generic EW equipment representative of that used in Air Force aircraft. The simulated environment consists of a 2000 x 2000 nautical mile gaming area, at altitudes of 0-100,000 feet and airspeeds up to 2000 knots. The signal environment consists of up to 63 simultaneous emitters created from 126 radio frequency sources which include communications, navigation, and friendly and hostile radar signals. Although the SEWT was initially conceived as a simulator to supplement flying in Electronic Warfare Officer Training (EWOT), this concept was changed on the basis of an ATC study in 1971/1972 which evaluated the feasibility of a non-flying EWOT program. Accordingly, with the introduction of the SEWT in January 1974, EWOT became a non-flying program utilizing the SEWT and the AN/ALQ-T4 Electronic Countermeasures simulator. In the original concept, 50 hours of SEWT training were to supplement approximately 70 hours of flying. Under the non-flying program; SEWT training was increased to 98 hours, T-4 training was also increased, and EWOT flying training was eliminated. As a result of this increased utilization requirement, increased production and surge capability requirements, and lower than predicted simulator reliability; ATC ROC 3-74 for SEWT expansion was prepared by ATC on 24 May 1974, and subsequently, validated at the Air Staff level. The proposed expansion includes a computer, instructor console, interface, and associ peripherals. PMD R-R4060(1) 81114F, dated 16 ober 1974 pertains. Contract award is expected in November 1975 and delivery/installation completion is anticipated for December 1977. The time frame for SEWT replacement is, in large part, dependent upon the technology and capability of future weapons systems such as the B-1, EF-111 and future Wild Weasel aircraft. SEWT replacement remains identified as a long term requirement, tentatively projected for the early to middle 1980s time frame.

Table V-3 provides the current flying training portions of the formal training programs just described. These figures are used as the baseline for projection of flying hour reductions which could conceivable be achieved by the full integration of simulators into the appropriate curricula.

TABLE V-3

FLYING HOURS/STUDENT (CURRENT PROGRAMS)

	UPT	PIT	IPIS	UNT
T-37	90	60		6.5
T-38	120	65	18.2	
T-43				105

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B. TRAINING DEVICE STATUS AND REQUIREMENTS

Improvements over the current programs are described in three progressive increments. The achievement of each increment is predicated upon a set of prerequisites to achieve substitution of simulator hours for flight hours without degradation to student proficiency upon graduation. Tables V-4, V-5a and b, and V-6 provide a perspective of the planned increments. Table V-4 presents the increments in terms of simulator utilization for the largest (in flying hours) of the ATC training programs, UPT, and PIT, with approximately 3000 and 1000 students proceeding through these programs per year. The last three columns of this Table represent three new simulators which will be described subsequently. Tables V-5a and b show the progressive reduction of flying hours accruing to simulator substitution into the UPT/PIT and UNT curricula. Note that the UNT, NBT and EWOT programs which were discussed earlier are not expected to offer further flight reduction possibilities in the foreseeable future since the NBT and EWOT programs are no fly programs, and the UNTS equipment is just now entering active use and the progression shown in Table V-5b is considered a part of Increment 1 planning. Table V-6 gives a breakdown of the flying hour programs associated with UPT and PIT for the current curricula and for the three planning increments. This breakdown in terms of training segments, indicates the area of interest applying to each of the increments. Note that the 1st Increment attacks the Instrument flying segment; the 2nd Increment attacks the Formation flying segment; and the 3rd Increment, the Contact and Navigation segments.

TABLE V-4

SIMULATOR UTILIZATION SUMMARY (ATC)
(HOURS/STUDENT)

	T-4 T-26 PROCEDURES & INSTRUMENTS		T-4 T-26 PROCEDURES		T-50 T-51 INSTRUMENTS		PIT-A FORMATION		PIT-B CONTACT		PIT-C NAVIGATION	
	T-37	T-38	T-37	T-38	T-37	T-38	T-37	T-38	T-37	T-38	T-37	T-38
	CURRENT		1ST INCREMENT									
UPT	33.5	39	12	12	45.6	49.6						
PIT	9	10.5	9	10.5	12	13						
			2ND INCREMENT									
UPT			12	12	45.6	49.6	4.2	4.2				
PIT			9	10.5	12	13	2.5	2.5				
			3RD INCREMENT									
UPT			12	12	45.6	49.6	4.2	4.2	15.8	10	4.7	15.1
PIT			9	10.5	18	14.8	2.5	2.5	8	8.4	0	0

TABLE V-5A

FLYING HOURS / STUDENT

INCREMENT	UPT				PIT				IPIS			
	S.Q.*	1	2	3	S.Q.	1	2	3	S.Q.	1	2	3
T-37	90	77	74.4	53.9	60	48	48	40				
T-38	120	99.2	96.6	71.5	65	52	52	43.6	18.2	14.3		11.7

* S.Q. = STATUS QUO

TABLE V-5B

UNT FLYING AND SIMULATOR HOURS/STUDENT

TRAINING AREA	UNT (N-V6A-A)	UNTS (N-V6A-B)	MUNTS[1] (N-V6A-B)	MUNT[2] (N-V6A-0)	UNT (N-V6A-D)
T-29	186	40	40	0	0
N-3	26	18	20	0	0
T-10	18	0	14	14	0
D-2	7	0	0	0	0
T-43	0	105	120	120	105
T-45	0	80	0	0	80
T-37	0	0	0	6.5	6.5
TOTAL FLYING	186	145	160	126.5	111.5
LAST CLASS	75-07		76-02[3]	76-18[4]	

(1) MODIFIED UNDERGRADUATE NAVIGATOR TRAINING SYSTEM

(2) MODIFIED UNDERGRADUATE NAVIGATOR TRAINING

(3) LAST CLASS TO FLY T-29s GRADUATED 28 AUGUST 1975

(4) LAST CLASS TO RECEIVE PARTIAL USE OF T-45 SIMULATOR

TABLE V-6

UPT FLYING HOURS/STUDENT

	CURRENT		1st INCREMENT		2nd INCREMENT		3rd INCREMENT	
	T-37	T-38	T-37	T-38	T-37	T-38	T-37	T-38
BASIC			13.0		13.0		13.0	
CONTACT	51.9	36.0	38.1	36.0	38.1	36.0	22.3	26.0
INSTRUMENTS	22.0	26.0	1.3	1.3	1.3	1.3	1.3	1.3
FORMATION	9.1	40.2	15.6	44.7	13.0	42.1	13.0	42.1
NAVIGATION	7.0	17.8	9.0	17.2	9.0	17.2	4.3	2.1
TOTAL	90.0	120.0	77.0	99.2	74.4	96.6	53.9	71.5

PIT FLYING HOURS/STUDENT

	CURRENT		1st INCREMENT		2nd INCREMENT		3rd INCREMENT	
	T-37	T-38	T-37	T-38	T-37	T-38	T-37	T-38
CONTACT	27.0	28.6	27.0	28.6	27.0	28.6	19.0	20.2
INSTRUMENTS	19.5	16.8	7.5	3.8	7.5	3.8	7.5	3.8
FORMATION	13.5	19.6	13.5	19.6	13.5	19.6	13.5	19.6
NAVIGATION	0	0	0	0	0	0	0	0
TOTAL	60.0	65.0	48.0	52.0	48.0	52.0	40.0	43.6

1. Increment 1

From an equipment standpoint, Increment 1 consists of the T-50 and T-51 Instrument Flight Simulators (UPT-IFS); the Undergraduate Navigator Trainer, T-45, and the T-43 UNT aircraft; the Simulator for Electronic Warfare Training (SEWT).

The UPT-IFS system consists of two T-50 and two T-51 simulator complexes per UPT base with one T-50 and one T-51 complex at the PIT base. The T-50 simulator models the T-37 aircraft and the T-51 simulator models the T-38 aircraft. The T-50 and T-51 simulators are identical except for the respective cockpit sections and aerodynamic computer software. Each IFS complex consists of four simulated aircraft cockpits mounted on six degree of freedom motion bases. Each cockpit is equipped with an on-axis infinity visual display and an on-board instructor station. The complex is supported by a single digital computation systems and a single two man operator station. The visual display is driven by a TV probe-terrain model visual generator. The visual generator is equipped with two terrain model boards that are time-shared between the four cockpits. Additionally, an electronic horizon generator is provided for each cockpit display to simulate visual flight above an undercast when not utilizing the terrain model board. One simulator complex for each aircraft at the first installation is configured with additional software and hardware features to provide software support for both the T-50 and T-51 simulators. The equipment design is fully integrated into the basic computer configuration as an additional processing capability without redesign or reassignment of the basic peripheral interface design. The purpose of the IFS Software Support Center is to provide software support for specific mission-related operations requirements and functional hardware/software related logistics requirements. The UPT-IFS program will not be fully implemented until late 1980 under present procurement schedules. As the IFS system is implemented at each site, all instrument training flights will be accomplished in the simulator with the exception of validation flights. This equates to approximately sixteen percent substitution of simulation for total programmed flying time within the UPT course. As experience is gained with the equipment and training validation data is accumulated, the substitution ratio will be adjusted.

A reduction of approximately 4 hours per student in the IPIS program is possible by the acquisition of an improved T-40 or similar system. To realize this reduction without significant degradation of training, an improved T-40 trainer must, at a minimum, include the following:

a. A visual system with a relatively narrow field of view (nominally 60 degree diagonal) with infinity image display.

b. An improved motion system with three degrees of freedom.

c. An on board instructor control panel.

d. Improved fidelity in instrument presentation.

Several prerequisites are necessary to achieve the management goals for flying reduction associated with this increment: a new syllabus which will result from the on-going ISD effort in UPT/PIT: the application of improved instructional methodology now undergoing testing at Williams AFB using the T-4/T-26 trainers and which includes the utilization of instructor pilots as trainer instructors and the use of proficiency advancement techniques through the instrument portion of the syllabus; the command wide implementation of the Instrument Flight Simulators now under procurement; and continued Major Command support of the IPIS program which will contain fewer flying hours for the graduate.

2. <u>Increment 2</u>

The realization of improvements described under Increment 1 are required to achieve the reduction in flying hours associated with this increment. As shown in Table V-6, a reduction in formation flight training is postulated through the substitution of a Formation Flight Trainer (PTT-A). This simulator will utilize the results of the Formation Flight Trainer which was evaluated at Williams AFB. It should be capable of close tactical and trail formation training. The display would represent state-of-the-art technology. A three degree of freedom motion base may be required subject to verification of the synergistic effects of motion and visual systems.

The visual trainer will provide student pilots an opportunity to attain some basic formation flight familiarity with skills before attempting them in flight. The formation flight trainer should have the following minimum features/capabilities:

a. Austere cockpit section.

b. Visual system of 200° horizontal - 25° to plus 65° vertical.

c. Interchangeable aircraft presentations (T-37/ T-38).

d. Interchangeable canopy bows (T-37/T-38).

e. Portable IP control panel.

f. Automatic demonstration capability for maneuvers such as:

(1) Turning rejoin,

(2) Cross under,

(3) Fingertip position,

(4) Route position,

(5) Echelon position, and

(6) Close train.

g. Horizon generator.

h. Roll capability of at least 0 to 60° left or right with a roll rate of up to 60° per second.

i. An indicated altitude range of plus or minus 5,000 feet above or below a standard altitude. (Flight dynamics need only be plus or minus 1,000 feet and a low angle of attack).

j. An indicated airspeed range of from 100 to 350 knots. Air speed shall be the only flight parameter displayed in the cockpit. (Indicators for both aircraft).

k. Landing configuration flight dynamics.

l. Computational system - small digital computer.

m. Variable automatic feedback system - a system of audio cues which will alert the student to his position error (i.e., high/low, forward/back, left/right).

n. Control loading system.

3. Increment 3

Substitution at this level is extremely difficult to forecast. Successful substitution will depend upon the favorable results of ongoing research in the Advanced Simulator for Undergraduate Pilot Training (ASUPT) to confirm hypotheses concerning motion and visual capabilities. Hands-on experience with the UPT-IFS will confirm or deny the estimates of substitution ratios of simulation for flying time. All estimates contained in this section of the Plan have an implicit 1:1 substitution ratio, but this may be erroneous. If ROCs were prepared as soon as initial research results become available from ASUPT (1975-77) the long lead times involved in the current system of device procurement would allow full Increment 3 substitution in the late 1980s time frame. Substitution of simulators to the levels represented by Increment 3 are clearly impossible by the 1978 time frame as called for in the OMB study.

In the UPT/PIT programs, Increment 3 substitution is based upon successful accomplishment of Increments 1 and 2, plus the acquisition and integration of training simulators to accomplishment of essential training tasks in the contact flying and pilot VFR navigation areas. Table V-6 indicates the planned reductions in flight training accruing to the successful integration of these systems into the UPT and PIT syllabi.

a. Contact Flight Simulator (PTT-B)

This simulator would principally be used to achieve substitution of simulator time for aircraft experience in the contact flying training area. Originally, the concept of a full mission simulator was considered to cover both contact and navigation; however, a more cost-effective approach to resolving the mutually incompatible visual requirements is believed to be separation of the simulation tasks into two devices. As presently projected, computer generated imagery could provide an adequate visual scene for all of the mission segments except VFR navigation which requires both color and high resolution, but less vertical field of view than the contact training tasks. The pancake window mosaic display and dome display suitable for contact simulation do not provide high resolution or high quality color which are believed to be essential for VFR navigation training. On the other hand, mirror/beam splitter mosaic type displays do not provide the vertical field of view required for air work in the contact training task, but are suitable for a Navigation simulator. The PTT-B contact flight simulator would require the following features:

(1) Wraparound visual display capable of providing cues for precision control maneuvers and aerobatics,

(2) A high fidelity motion system capable of simulating g-forces associated with aerobatics, and

(3) Advanced instructional features.

b. Navigation Flight Simulator (PTT-C)

A film type device or camera model could provide good simulation for navigation training and could conceivably be accomplished in a less sophisticated device than that needed for contact training with its attendant great demands for somatic cues and large vertical field of view. The visual scene will be required to be of high fidelity in terms of color and resolution for identification of cultural and natural features for navigation checkpoints. A wide gaming area is desirable to provide variety in the training task and to offer various levels of task difficulty. Advanced instructional features comparable to those provided for the contact flight simulator are also required. The need for motion should be addressed at an early date prior to further definition of this device; however, cost estimates should include at least a three degree of freedom motion base.

C. PROGRAM DATA

Quantity requirements for new simulators were based upon nominal student loadings, a one-to-one transfer ratio for simulator time and flight time, and a utilization rate of 3000 hours per year cockpit position. Table V-7 is a summary of the resultant requirements. These will change

TABLE V-7

QUANTITY REQUIREMENTS FOR NEW ATC SIMULATORS

SIMULATORS	UPT	PIT	IPIS	TOTALS
PTT-A	16	1	- -	17
PTT-B	26	6	- -	32
PTT-C	20	- -	- -	20
T-40 IMPROVED	- -	- -	2	2

BASED ON: UTILIZATION RATE OF 12 HRS/DAY; 5 DAYS/WEEK; 50 WEEKS/YEAR.

3000 STUDENTS/YEAR FOR UPT

1000 STUDENTS/YEAR FOR PIT
(500 FOR T-37/500 FOR T-38)

250 STUDENTS/YEAR FOR IPIS

in direct proportion to changes in the true value of the parameters noted. Figure V-1 is the planning schedule for the simulators and other training media discussed in association with the three incremental improvements. The time span between events is based upon historical experience for programs of comparable magnitude.

D. IMPACT OF NEW TRAINING CAPABILITIES ON TRAINING PROGRAMS

A cautious approach to simulator substitution for flying training must be adopted to prevent loss of graduate proficiency and to assure the receiving commands of students prepared for transition training. The Air Training Command has postulated a progressive program in the increments described which has the potential of reducing flying training in UPT and PIT to the levels summarized in Table V-8, which shows the relationship between simulator time and flying time for the two major programs. The ATC is not recommending reductions to the ultimate level of 125.4 hours per graduating UPT student; however, these are useful goals to use as planning guides during the next decade of program change.

E. COMMAND PRIORITIZATION

The Air Training Command has established a priority listing for the acquisition of training devices considering the relative importance of each program along with the urgency of the requirement. That prioritization is provided below along with a Command technology assessment using the following code:

- A - In use or in procurement.

- B - Modification of existing equipment.

- C - New capability needed: Technology is state-of-the-art.

- D - New capability needed: New technology is required.

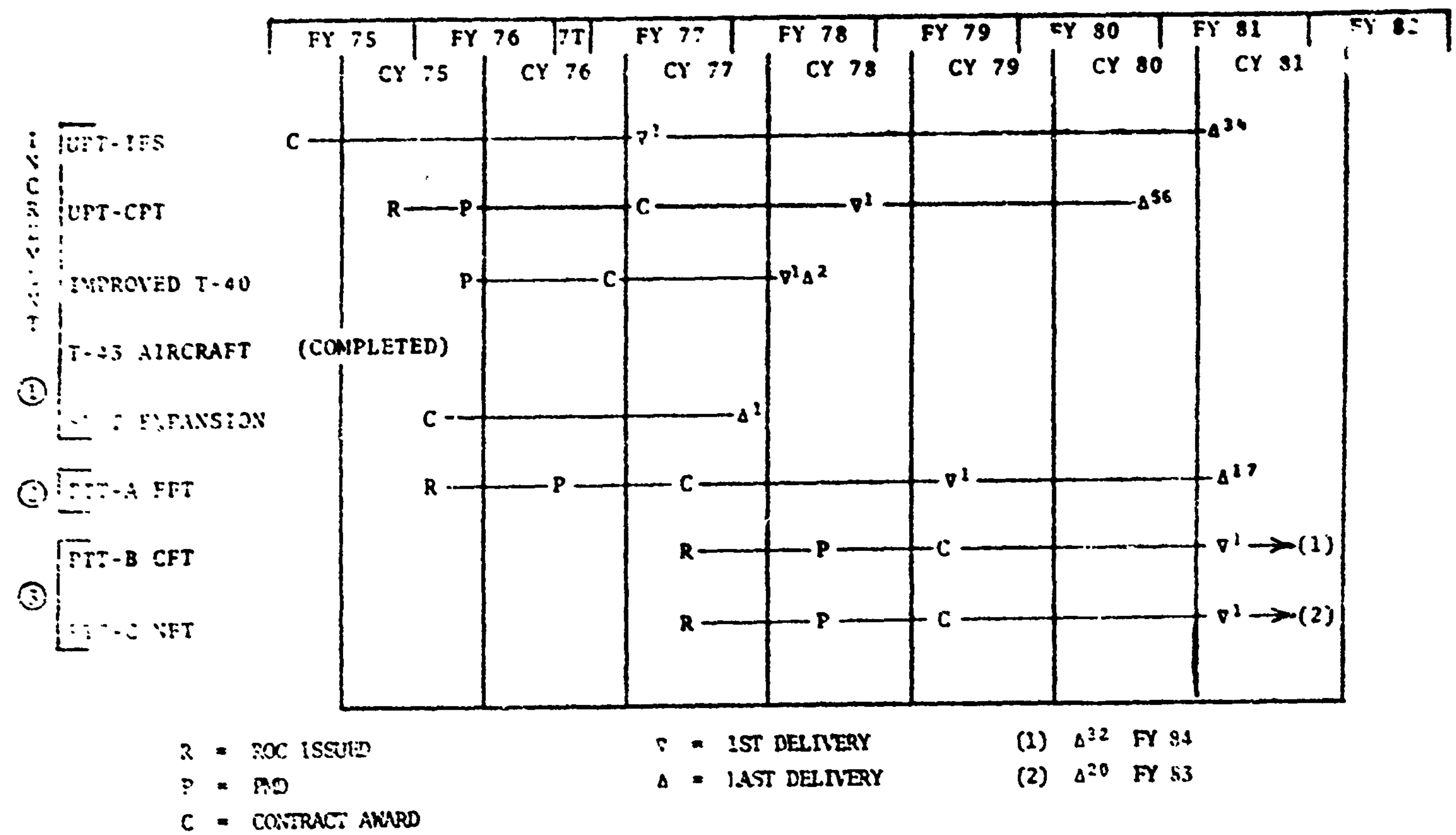


FIGURE V-1. PLANNING SCHEDULE FOR ATC SIMULATORS

TABLE V-8

TRAINING PROGRAM SUMMARY

AIR TRAINING COMMAND

	CURRENT		INCREMENT 1		INCREMENT 2		INCREMENT 3	
	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME
UPT								
PILOT	72.5	210	95.2	176.2	103.6	171.0	149.2	125.4
#STUDENTS/YEAR	3000							
TOTAL/YEAR (1000's HOURS)	217.5	630	285.6	528.6	310.8	513.0	447.5	376.2
% CHANGE	---	---	31.0	16.0	43.0	19.0	106.0	40.0
PIT								
PILOT	19.5	125	44.5	100.0	49.5	100.0	73.7	83.6
#STUDENTS/YEAR	1000							
TOTAL/YEAR (1000's HOURS)	19.5	125	44.5	100.0	49.5	100.0	73.7	83.6
% CHANGE	---	---	128.0	20.0	154.0	20.0	278.0	33.0

	COMMAND PRIORITIES	MASTER PLAN INCREMENT NO.
1.	UNTS for UNT (A)	1
2.	UPT-IFS for UPT/PIT (A)	1
3.	CPT for UPT/PIT (B or C)	1
4.	SEWT Expansion for EWOT (B)	1
5.	Formation Flight Simulator (PTT-A) (C)	2
6.	UPT-IFS for IPIS (C)	-
7.	CONTACT FLIGHT SIMULATOR (PTT-B) (D)	3
8.	Navigation Flight Simulator (PTT-C) (D)	3
9.	Full Mission Simulator for NBT (D)	-
10.	SEWT Replacement for EWOT (D)	-
11.	Improved T-40 for IPIS (B)	1

The priority listing is related to the planning increments as shown above. Item 11 which is included in Increment 1 for IPIS, is an alternative to the utilization of a UPT-IFS complex (Item 6) modified for IPIS for fixed wing and helicopter training. No attempt has been made in this Plan to make an engineering or economic choice of these alternatives; however, this is clearly an item for additional investigation. Item 3 is implicit in the use of the T-4/T-26 Flight Instrument Trainers to serve as cockpit procedures trainers once the UPT-IFS has become operational. The full mission simulator for NBT and the SEWT replacement for EWOT remain identified as long-term requirements. Research and analysis for these acquisition items are dependent upon training requirements generated by the technology and capabilities of future aircraft systems.

SECTION VI

TACTICAL AIR COMMAND (TAC)

A. GENERAL

The Tactical Air Command conducts Combat Crew Training Schools/Replacement Training Units (CCTS/RTU) for the F-4, RF-4, F-111, F-15, A-7D and AC-130 aircraft, using the Instructional Systems Development (ISD) approach to training. The CCTS/RTU includes Transition Training (Phase I) and Mission Qualification Training (Phase II). The CCTS/RTU provide combat crews for the Tactical Air Forces (TAFs) as well as friendly foreign nations. The various commands are responsible for Continuation Training (Phase III) in the operational units.

The Tactical Air Command is fully committed to the Instructional Systems Development approach for defining all aircrew training programs. TAC has fully implemented the ISD approach and has achieved the maximum reduction in flying hours through optimum use of available simulators and training devices for the above listed six CCTS/RTU. The results of this effort are shown in Table VI-1. The TAC ISD teams are presently applying the ISD approach to Continuation Training for the above noted six weapon systems. Redefined AFM 51 series training manuals were recently completed in the Spring of 1975.

Further significant reductions in Phase I, II and III training flight hours (beyond these ISD syllabi) can only be achieved through modifying the RF-4C simulators with new motion and visual systems, modifying the F-4E simulators with visual systems and G-seat/G-suit/buffet, acquiring F-4E full mission simulators, adding DRLMS and visual systems to the F-111A/D/F simulators and adding visual systems to A-7D and F-15 simulators. TAC has submitted Required Operational Capability (ROC) documentation to add visual systems to the A-7D simulators and to modify the F-4E simulators with visual systems and G-seat/G-suit/buffet, and acquire new F-4E full mission simulators.

TAC has established ISD Teams for new aircraft (F-15, A-10 and E-3A) procurements. The task analyses have been essentially completed for the F-15 and A-10, and the E-3A task analysis will be completed in October 1975. The

TABLE VI-1

IMPACT OF ISD APPROACH ON TAC CCTS/RTU AIRCREW TRAINING

AIRCRAFT	FLYING HOUR REDUCTION HOURS (%)		FUEL SAVED (MILLION GALLON/YEAR)
F-4 D/E	5683	(15)	7.44
RF-4	666	(15)	.88
F-111 A/D/F	94	(3)	.14
TOTAL	6443		8.46
A-7D		(1)	(1)
AC-130		(1)	(1)
F-15		(1)	(1)

(1) ISD APPROACH WAS APPLIED TO INITIAL SYLLABUS

Conversion Course Syllabus for the F-15 was completed in January 1975 and the Basic Course Syllabus will be completed in January 1976. The Conversion Course Syllabi for the A-10 and E-3A are scheduled to be completed by January 1976. The F-16 ISD Team will be established to start a task analysis in January 1976.

TAC will also apply the ISD approach to the F-4 Wild Weasel and EF-111A Tactical Jamming Systems.

TAC has participated with other MAJCOMs in providing flying time reduction estimates as justification for simulators. These estimates have been accompanied by the caveat that the reductions are predicated on delivery of training devices which provide the capability to satisfy stated training requirements. These caveats have been lost in the annual budget exercises and estimated reductions have become Five Year Defense Program (FYDP) flying time allocations. It must be recognized that TAC estimates contained in this document are not based on statistically valid transfer of training studies and therefore cannot be used as the basis for future flying hour allocations. Future flying hour allocations should be based on the proven utility of training devices in established aircrew training programs.

TAC utilized the OMB goals for reductions in flying hours as a set of management objectives rather than as actual goal figures. Simulators were considered as a training medium along a continuum of media (from study carrels through aircraft) according to the ISD "least cost training device first" concept.

The Secretary of Defense recently established a goal for flying hour reductions by FY 1981. This goal provides for a decrease of 25 percent in training and proficiency flights and states that combat skill levels will be maintained through maximum use of simulators. The first step in meeting this challenge is to precisely determine what simulators can do to fulfill training needs. In order to accomplish this, it is necessary to establish an Aircrew Simulator Certification Program.

Aircrew Simulator Certification is the process of specifying the training capability of a ground-based device (simulator) in a given aircrew training program. The process will include:

1. Identification of tasks to be taught.

2. Task by task determination of the degree that the criterion objectives can effectively be attained in the device being certified.

3. Detailed list of minimum operable subsystems for each mission phase (e.g., transition, air-to-ground, air refueling, etc.).

The program will provide quantitative task element level data for making tradeoffs of simulation training for flying training.

ISD is a deliberate and orderly process for planning and developing instructional programs which ensure that personnel are taught the knowledge, skills, and attitudes essential for successful job performance. To perform this process, the ISD Team conducts a task analysis which lists all aircrew tasks/activities, and establishes the minimum standard of performance (criterion objective). It is these objectives which will serve as the baseline for the Aircrew Simulator Certification Program.

The CCTS/RTU and Continuation Training programs are summarized in Table VI-2.

B. TRAINING DEVICE STATUS AND REQUIREMENTS

Simulators and training devices now owned by TAC are being utilized to the maximum extent possible based on training requirements, equipment performance capabilities and maintenance costs. The current and projected TAC training equipment is summarized in Table VI-3. These equipments are for use in CCTS/RTU and operational training.

The projected wide-angle visual systems and digital data base/radar simulation are based on satisfactory completion of R&D programs summarized in Section II, Overview of Simulator Technology. The six degree of freedom motion system is a production item and is available from several sources. The digital computers are production items and are available from a variety of sources.

TABLE VI-2

TAC FORMAL AIRCREW TRAINING PROGRAMS

AIRCRAFT	CREW MEMBERS(1)	TYPE TRAINING	FLIGHT HOURS PER CREW	NUMBER OF CREWS/YR (2)
F-4 D/E	AC, WSO	CCTS CONTINUATION(3)	92 228	325 306
RF-4	AC, WSO	CCTS CONTINUATION(3)	75 253	49 126
F-111 A/D/F	AC, WSO	CCTS CONTINUATION(3)	89 264	72 182
A-7D	AC	CCTS CONTINUATION(3)	80 235	84 186
AC-130	AC, CP, N, FE, FCO, IRO, EWO, LLLTVO, IO, WM	CCTS CONTINUATION(3)	45 240	18 20

(1) AC, AIRCRAFT COMMANDER
CP, COPILOT
WSO, WEAPON SYSTEMS OPERATOR
FE, FLIGHT ENGINEER
N, NAVIGATOR
FCO, FIRE CONTROL OFFICER
IRO, INFRARED OPERATOR
LLLTVO, LOW LIGHT LEVEL TV OPERATOR
EWO, ELECTRONIC WARFARE OFFICER
WM, WEAPONS MECHANICS
IO, ILLUMINATOR OPERATOR

(2) FY 75

(3) ANNUAL REQUIREMENT

TABLE VI-3

TAC TRAINING EQUIPMENT SUMMARY

TRAINING PROGRAM	TRAINERS/SIMULATORS		
	DESIGNATION	STATUS	FEATURES
F-4D/E	COCKPIT PROCEDURES TRAINER	CURRENT	NON-FUNCTIONAL STATIC DISPLAY, SOUND SLIDE CUES
	FLIGHT SIMULATOR	CURRENT	COCKPIT, MOTION - TWO DEGREES OF FREEDOM, RADAR ANALOG, NO VISUAL, COMPUTERS - DIGITAL (F-4E)
	FLIGHT SIMULATOR	FUTURE	MODIFY FLIGHT SIMULATOR. ADD: LIMITED VISUAL G-SEAT/G-SUIT/BUFFET, ADAPTIVE TRAINING SYSTEM
	FULL MISSION SIMULATOR F-4E	FUTURE	FLIGHT SIMULATOR, MOTION - SIX DEGREES OF FREEDOM, VISUAL - WIDE ANGLE, RADAR-DIGITAL DATA BASE, COMPUTERS - ALL DIGITAL PLUS ADAPTIVE TRAINING SYSTEM
	NAVIGATION TRAINER	FUTURE	MOTION PICTURE TYPE
RF-4	COCKPIT PROCEDURES TRAINER	CURRENT	SAME TYPE AS F-4E COCKPIT PROCEDURES TRAINER
	FLIGHT SIMULATOR	CURRENT	SAME TYPE AS F-4E FLIGHT SIMULATOR EXCEPT COMPUTER DC ANALOG
	FULL MISSION SIMULATOR	FUTURE	SAME TYPE AS FOR F-4E PLUS SIMULATION OF AVIONICS
	NAVIGATION TRAINER	FUTURE	SAME TYPE AS FOR F-4D/E

TABLE VI-3

TAC TRAINING EQUIPMENT SUMMARY (CONTINUED)

TRAINING PROGRAM	TRAINERS/SIMULATORS		
	DESIGNATION	STATUS	FEATURES
F-111 A/D/F	FLIGHT SIMULATOR	CURRENT	COCKPIT, MOTION - FIVE DEGREES OF FREEDOM, COMPUTER - DIGITAL, LIMITED RADAR, NO VISUAL
	FULL MISSION SIMULATOR	FUTURE	MODIFY FLIGHT SIMULATOR, ADD: VISUAL - WIDE ANGLE, RADAR - HIGH RESOLUTION DIGITAL RADAR LANDMASS
	COCKPIT PROCEDURES TRAINER	CURRENT	COCKPIT - NON-FUNCTIONAL, SOUND SLIDE CUES
	NAVIGATION TRAINER	FUTURE	SAME TYPE AS F-4D/E NAVIGATION TRAINER
A-7D	FLIGHT SIMULATOR	CURRENT	COCKPIT, MOTION - FOUR DEGREES OF FREEDOM, COMPUTER - DIGITAL, RADAR ANALOG, MODIFY, ADD LIMITED VISUAL, ADAPTIVE TRAINING SYSTEM
	FULL MISSION SIMULATOR	FUTURE	MODIFY FLT SIMULATOR, ADD: VISUAL WIDE-ANGLE
	NAVIGATION TRAINER	FUTURE	SAME TYPE AS F-4D/E NAVIGATION TRAINER
	COCKPIT PROCEDURES TRAINER	CURRENT	FULLY FUNCTIONAL/DYNAMIC COCKPIT PROCEDURES TRAINER

TABLE VI-3

TAC TRAINING EQUIPMENT SUMMARY (CONTINUED)

TRAINING PROGRAM	TRAINERS/SIMULATORS		
	DESIGNATION	STATUS	FEATURES
AC-130	FIRE CONTROL INTEGRATED SYSTEM TRAINER (FIST)	CURRENT	RDT&E PROTOTYPE PROCEDURAL TRAINING - IR, LLLTV AND RADAR OPERATORS AND FIRE CONTROL OFFICER
	ENHANCED FIST	FUTURE	RDT&E PROTOTYPE PROCEDURAL TRAINING - ADD: PILOT AND NAVIGATION POSITIONS TO FIST
F-15	COCKPIT PROCEDURES TRAINER	PROCUREMENT	NON-FUNCTIONAL STATIC DISPLAY, SOUND SLIDE CUES
	FLIGHT SIMULATOR	PROCUREMENT	COCKPIT, MOTION - SIX DEGREES OF FREEDOM, COMPUTER - DIGITAL, NO VISUAL
	FULL MISSION SIMULATOR	FUTURE	ADD WIDE-ANGLE VISUAL SYSTEM TO FLIGHT SIMULATOR

TABLE VI-3

TAC TRAINING EQUIPMENT SUMMARY (CONTINUED)

TRAINING PROGRAM	TRAINERS/SIMULATORS		
	DESIGNATION	STATUS	FEATURES
A-10	INSTRUMENT FLIGHT SIMULATOR	FUTURE	COCKPIT, MOTION - SIX DEGREES OF FREEDOM, VISUAL - LIMITED, COMPUTER - DIGITAL
	COCKPIT PROCEDURES TRAINER		NONFUNCTIONAL STATIC DISPLAY SOUND SLIDE CUES
A-10	FLIGHT SIMULATOR	FUTURE	COCKPIT, MOTION - SIX DEGREES OF FREEDOM, VISUAL - WIDE ANGLE, COMPUTER - DIGITAL
F-16	INSTRUMENT FLIGHT SIMULATOR	FUTURE	COCKPIT, MOTION - SIX DEGREES OF FREEDOM VISUAL - LIMITED. COMPUTER - DIGITAL
	FLIGHT SIMULATOR	FUTURE	ADD WIDE ANGLE VISUAL TO IFS
	COCKPIT PROCEDURES TRAINER	FUTURE	NONFUNCTIONAL, STATIC DISPLAY, SOUND SLIDE CUES
E-3A	COCKPIT PROCEDURES TRAINER	PROCURE-MENT	NONFUNCTIONAL LIGHTED CAB MOCKUP
	MISSION SIMULATOR	PROCURE-MENT	MISSION CREW COMPARTMENT AND SIMULATOR SUPPORT CAPSULE, COMPUTER - DIGITAL
	FLIGHT SIMULATOR	PROCURE-MENT	COCKPIT, MOTION - SIX DEGREES OF FREEDOM (SYNERGISTIC), COMPUTER - DIGITAL, VISUAL - LIMITED - DAY/NIGHT AND INFLIGHT REFUELING
	ENHANCED MISSION SIMULATOR	FUTURE	ADD INSTRUCTOR MULTIPURPOSE CONSOLE TO SIM SUPPORT CAPSULE, ADD RADIO OPERATOR AND RADAR MAINTENANCE TECH POSITION TO MISSION CAPSULE

TABLE VI-3

TAC TRAINING EQUIPMENT SUMMARY (CONTINUED)

TRAINING PROGRAM	TRAINERS/SIMULATORS		
	DESIGNATION	STATUS	FEATURES
F-4E WILD WEASEL	FLIGHT SIMULATOR	FUTURE	MODIFY F-4E FLIGHT SIMULATOR TO ADD: APR-38 SYSTEM, LIMITED VISUAL, G SEAT/G-SUIT/BUFFET, COMPUTER - DIGITAL, AVIONICS SIMULATION, ADAPTIVE TRAINING SYSTEM
	NAVIGATION TRAINER		MOTION PICTURE TYPE
EF-111A TACTICAL JAMMING SYSTEM	FLIGHT SIMULATOR	FUTURE	COCKPIT MOTION - SIX DEGREES OF FREEDOM, VISUAL (NOT DEFINED)
	NAVIGATION TRAINER	FUTURE	MOTION PICTURE TYPE
DC-130	DRONE/RPV MISSION SIMULATOR	FUTURE	DUPLICATE LAUNCH AND CONTROL CREW STATIONS IN DC-130; PROVIDE MULTIPLE DRONE CONTROL CAPABILITY

The current and projected flying times per aircrew (assuming future simulators become available) are shown under Section D for the F-4E, RF-4, F-111A/D/F, A-7D and AC-130. Tentative estimates for the F-15, A-10, F-16, E-3A, F-4E WW and EF-111A Tactical Jamming System (TJS) are in various stages of development.

1. F-4E

The current flight simulator is capable of providing instrument training. The motion system and analog radar have marginal fidelity. The modification of the existing 16 F-4E simulators and an acquisition of a full mission simulator capability will permit training in take-offs, approaches, landings, navigation, air-to-ground weapon delivery and air-to-air combat under both radar and visual conditions. Through use of the full mission simulator, TAC estimates that the CCTS (Transition) flying time could be reduced from the current 92 hours to between 90 and 60 hours. In Continuation Training the flying time could be reduced as much as 36 hours from the current 228 hour program. The exact reduction will depend on the proven utility of the simulation system.

2. RF-4C

The current flight simulator has serious deficiencies which result in the use of the simulator as a cockpit checklist procedures trainer and a limited instrument procedures trainer. Most serious of the deficiencies is its use of an analog computer system coupled with an analog radar data base. It also has limited motion and no visual system. From an instructional capability, it has no capability to score a mission on the accuracy of the radar navigation to achieve planned photography. Age and configuration control pose a serious compromise to continued use of the simulators even as procedures trainers as new and improved avionics and sensor systems are procured for the RF-4C. Future systems now under evaluation and test cannot adequately be simulated in the existing devices. As the RF-4C is expected to be in the active inventory for some time, the simulators will require extensive modification to be able to provide adequate training support throughout the life of the aircraft. With full-up modification to digital computer and radar landmass coupled with an improved motion system and visual capabilities, TAC estimates that the present 75 hour formal CCT course could be reduced up to 35 hours and continuation training could be reduced as much as 53 hours per year per crew. The exact reduction will depend on the proven utility of the simulation system. A modular ROC is being developed to request the required modifications in stages based upon the need to correct existing deficiencies and provide the improved capabilities of the updates to the RF-4C.

3. F-111A/D/F

The current simulator has no visual capability and only a limited radar capability. The addition of a limited visual system, with a growth potential to wide angle, and high resolution digital radar to the existing six TAC simulators and an additional F-111F simulator will permit training in visual and instrument takeoffs, landings, approaches and low-level navigation with air-to-ground capability. Through use of these add-on capabilities, TAC estimates that the CCTS (transition) flying time could be reduced to 62-80 hours. In Continuation Training, the flying time could be reduced as much as 48 hours from the current program. The exact reduction will depend on the proven utility of the simulation system.

4. A-7D

The current flight simulator has no visual capability. Addition of a limited visual system to the 3 TAC and 1 Air National Guard devices will permit training in visual takeoffs, approaches, landings, navigation and limited air-to-ground. This capability was funded in FY 75.

An additional wide angle visual system is to be procured for one of the three TAC simulators. The one limited visual system would then be transferred to a second ANG simulator. The wide angle visual system will be utilized in the A-7 CCTS. It will permit training previously available with the limited visual, plus air-to-ground and limited air-to-air. Using the full visual TAC estimates that the transition flying time could be reduced to approximately 67 hours. In Continuation Training, the flying time could be reduced as much as 62 hours from the current 235 hour program. The exact reduction will depend on the proven utility of the simulation system. TAC submitted a ROC in April 1972.

5. AC-130

TAC is currently utilizing the Fire Control Integrated System Trainer (FIST) for operational training of AC-130 crews. This trainer was developed as a prototype part task trainer (PTT) to study the training effects of a PTT on multiplace crew training and for possible sensor simulation applications to other weapons systems. The FIST is being utilized to train low light level television, infrared and electronics operators and the fire control officers. The requirement for an AC-130 flight simulator has been deleted from the C-130 ROC submitted in September 1971. The requirement for an AC-130 simulator was deleted because of the small number of AC-130 aircraft planned to remain in the regular Air Force. The FIST only partially satisfies the requirement for an AC-130 trainer. The requirement for an enhanced FIST, providing additional training capability for the pilot and navigator and a real time sensor/ballistic capability, is being studied by TAC/DOXS and will be submitted formally in the near future; therefore, no time-lined chart is presented in the scheduled summary.

6. F-15

The current status of the F-15A Aircrew Training Devices (ATDs) and total requirements estimated for each device are near final completion. The first Cockpit Procedure Trainer (CPT) completed its acceptance test on 8 May 1975, and was delivered to the 58 TFTW, Luke AFB, Arizona, 22 May 1975. The F-15 flight simulator system integration was scheduled to be completed by August 1975. In plant acceptance will follow. The nonvisual simulator is scheduled to be ready for training in February 1976 at Luke AFB, Arizona. The next base to be equipped with follow-on ATDs is Langley AFB, Virginia. TAC requires two flight simulators per TFW for visual interface in the future, and one CPT per TFS for continuation training. The F-15 ROC for a visual requirement is currently being rewritten and should be submitted to the Air Staff by FY 2/76. A Program Management Directive (PMD) is anticipated in Fiscal Quarter 4/76 with an initial F-15 visual system capability estimated in Fiscal Quarter 4/79.

7. A-10

A joint TAC/AFSC A-10 Aircrew Training Devices Trade Study was completed in May 1975. The trade study determined minimum training devices required to conduct A-10 aircrew training considering training effectiveness, cost effectiveness, and ecological benefits. Based on preliminary trade study data and the urgency to procure long lead training devices, direction was given in January 1975 to procure two instrument flight simulators (IFSs) and six dual cockpit full mission simulators (FMSs) (in addition to previously planned CPTs, AETs, and study carrels). The two IFSs will contain state-of-the-art limited visual display systems. The FMSs will include a full field of view visual system capable of presenting airborne flight members/targets as well as a wide variety of ground targets, including moving vehicles. An engineering development program, discussed in Section II, will be conducted to determine a candidate visual system for the full mission simulators. The IFSs will be located at the A-10 TFTW and permit training in all phases of instrument and limited visual flight training, takeoffs and landings, IFR navigation missions, limited air-to-ground weapons delivery, electronic warfare countermeasures, and dynamic integration of aircraft emergency procedures into flight situations.

The FMSs will permit additional training in IFR and VFR takeoffs, landings and approaches (including overhead patterns, and closed patterns); close, route and tactical formation with at least one other aircraft; offensive; defensive aerial combat maneuvering; escort formation; enemy defenses, such as AAA and SAM; air refueling; and full ground attack roles.

The trade study projected the following flying time reductions:

a. Ten hour student and support time reduction in CCT with the instrument flight simulators (from 102 hours to 92 hours and from 74 hours to 64 hours).

b. Thirty-four hour student and twenty-eight hour support time reduction in CCT with the full mission simulator. (From 102 hours to 68 hours and from 74 hours to 46 hours).

c. Ninety-six hour operational pilot reduction per year with the full mission simulator (from 288 hours to 192 hours).

The exact reduction will depend on the proven utility of the simulation system.

8. F-16 Air Combat Fighter (ACF)

a. TAC Requirements:

(1) Mission Simulator - must provide realistic representation of the mission environment to include the cockpit identical to aircraft configuration and external references including all key visual, audible, and sensory cues. To provide an opponent for air combat and a partner for flight tactics training in both air-to-air and air-to ground roles, the simulator must be designed as a dual unit consisting of two basically independent cockpits, displays, and motion systems capable of interacting during other than single ship training. A more detailed description of this requirement has been provided to the F-16 SPO and the Simulator SPO.

(2) Two mission simulators will be required for the training wing, and one mission simulator for each operational wing.

(3) Cockpit Procedures Trainer - A nonfunctional cockpit procedures trainer similar to those being employed in F-4 and F-15 training. The CPT must be a full scale mockup of the cockpit with all controls (throttle, stick, knobs, levers) operating with a response and feel similar to those of the aircraft. The controls, however, perform no function. All indicators, gauges, and lights are realistically represented, but also nonfunctional. Visual cues are provided by a reverse projection 35 MM slide display located above the instrument panel. A cassette audio tape player capable of programmed slide advance and pause will control the slide display and provide instructional programs, exercises, and audio cues. Adjacent to the slide display should be a color video tape (3/4") display. Programs requiring dynamic display should be selected for this media. The F-16 SPO has been provided a more detailed description of CPT requirements and will procure F-16 CPTs.

(4) Four CPTs are required for the Training Wing and one CPT is required for each operational wing.

b. Procurement Plan

Specifications for an Instrument Flight Simulator (IFS) which will serve as the core subsystem for the mission simulator are currently being developed. The instrument flight simulator will serve as an interim training device while awaiting the assessment of various technologies for the full mission simulator. Required delivery of the initial IFS is to be in October 1979, after the start of TAC initial aircrew training. The IFS will be built with the necessary growth provisions to expand to full mission simulator status upon completion of ongoing Engineering Development Programs (EDP). The F-16 Cockpit Procedures Trainer is planned to be ready for training by November 1978.

9. E-3A

The 411L (AWACS) program is under contract with The Boeing Company for the aircraft and three major training devices:

a. The Flight Simulator:

Is to be utilized in training the two pilot and flight engineer crew members of the flight crew. There is no provision in the simulator for training the navigator flight crew member. The simulator features a six-degree of freedom synergistic motion system, a digital computer and a 36 x 48 degree field of view visual system (model board). The visual system will permit training in instruments and visual takeoffs, approaches, landings, navigation, station keeping and air-to-air refueling. The flight simulator will be configured to the Boeing 707-320B aircraft and will include specialized AWACS components. The visual air refueling envelope will be limited to the extent dictated by the state-of-the-art in visual systems. It is considered adequate to provide training from 2 NM behind, and 1000 feet below the tanker to actual hookup. Once the receiver is out of the envelope, he will lose visual contact with the tanker. The flight simulator will have a capability for "Split Training." When operating in the "Split Training" mode, pilots may be trained without a flight engineer on board and vice versa. Additionally, pilots and flight engineers can receive independent training on the same simulator flight.

Changes in program schedules and ongoing system decisions could have impact on the projected estimates of numbers of personnel to be trained on the equipment. Based on current program schedules, the first formal training course will begin in November 1976 at Tinker AFB, Oklahoma. If full production is authorized, there will be a requirement for 71 AWACS aircrews. The current production schedule will require 15 aircrews (45 personnel) to receive initial training annually, beginning November 1976. This steady crew load, plus a one-third personnel turnover annually will result in an annual requirement for initial training of 20 aircrews (60 personnel) and associated continuation training. A steady-state load on the flight simulator is estimated to be 1500 hours the first year of operational training. At a full load of 71 aircrews, 24 aircrews (72 personnel) will require initial training each year (approximately 1200 hours) plus continuation training which will amount to approximately 2950 hours annually.

b. The Mission Simulator:

Is to be utilized in training 10 of the 13 mission crew personnel (AFSCs 1716, 1744D, 1744G, 276XD and A305X4). There is presently no capability to train the following mission crew members in the simulator: Airborne Radio Operator (AFSC A293X3), Avionics Communications Technician (AFSC A328X0), and the Radar Maintenance Technician (AFSC A328X2). TAC has identified a requirement to add the Radio Operator and Radar Maintenance Technician positions to the simulator, along with an associated fault insertion capability. These additions will be accomplished through ECP action. The simulator, as currently designed, will support integrated mission crew training in the control of air-to-air intercepts, close air support, air-to-air refueling, aerial delivery missions, maritime surveillance, aerial surveillance and surveillance of ground forces. Changes in program schedules and ongoing systems decisions could impact the projected estimates of numbers of personnel to be trained on the equipment. Based on current program schedules, the first formal training courses will begin in November 1976 at Tinker AFB, Oklahoma. If full production is authorized, there will be a requirement for 71 AWACS aircrews. The current production schedule, coupled with the current simulator capability, will require 15 aircrews (150 personnel to receive initial training annually beginning in November 1976. This steady crew load, plus a one-third personnel turnover annually will result in an annual requirement for initial training of 20 aircrews (200 personnel) and associated continuation training. A steady-state load on the mission simulator is estimated to be 2400 hours the first year of operational training. Since the simulator utilizes the same computer as the aircraft, the mission simulator will also have a partial capability to check the Airborne Operational Computer Program (AOCP), which will be utilized on the

AWACS aircraft. The requirement to check the AOCP will levy an additional requirement for 1000 hours annually. At a full load of 71 aircrews, 24 aircrews (240 personnel) will require initial training each year (approximately 2160 hours) plus continuation training which will amount to approximately 3540 hours annually.

c. <u>The Individual Positional Trainer (IPT)</u>:

Is currently scheduled for ATC ownership and is to be located at Tinker AFB, Oklahoma. The IPT is primarily designed to train AFSCs 17XX and 276X0 in AWACS multipurpose console (MPC) switchology and symbology, but will also allow some computer operator (AFSC A305X4) training. The IPT is scheduled for delivery in October 1977, dependent upon a favorable DSARC procurement decision during FY 76.

10. <u>F-4E Wild Weasel (WW)</u>

A Tactical Air Force ROC was submitted in 1973 for two simulators and two electronic warfare PTTs. A go-ahead to modify two F-4E simulators to APR-38 configuration has been given to Ogden ALC. The APR-38 configured simulators will undergo further modification as a part of the Step 1 modification to the F-4E simulator fleet to satisfy part of TAF ROC 326-74 The Step 1 modification will add a limited visual system, G-Seat/G-Suit/Buffet, and AFTS to the F-4E simulator fleet. The need for electronic warfare PTTs will be readdressed as a result of a task analytic effort recently requested by TAC as part of the APR-38 modification contract. A requirement exists for low cost low level motion picture type navigation trainers which would be the same kind as those proposed for several of the other TAC weapon system training programs. Training syllabi have not been developed.

11. <u>EF-111A Tactical Jamming System (TJS)</u>

TAC has identified a need for two EF-111A mission simulators. An aircraft PMD containing simulator procurement information is expected in FY 1/76, but simulator procurement direction in a PMD could be delayed until an aircraft production decision is reached. A simulation requirements package is in process at TAC. The requirement for EW PTTs will be determined as a result of a task analysis effort which will be requested as the first deliverable item for the mission simulator procurement.

A requirement exists for low cost low level motion picture type navigation trainers which would be the same kind as those proposed for several of the other TAC weapon system training programs.

12. DC-130

TAC submitted a ROC in September 1971 for a DC-130 simulator as a part of the C-130 flight simulator requirement. The DC-130 portion of the C-130 simulator has been deleted and TAC staff action is in progress to transfer the requirement to a DC-130 simulator ROC TAC crews will be able to receive limited training on th 'AC Drone Flight Simulator (SAC ROC 5-73) scheduled for ins.. lation during FY 76, while awaiting delivery of the TAC drone simulator. The drone flight simulator is required by FY 7T but current plans call for delivery in FY 1/80. The new TAC simulator ROC will stress full simulation of the Multiple Drone Control (MDC) system as it is employed in the electronic warfare support mission. Emphasis will be placed on exercising the mission (flight) planning requirements for large numbers of drone sorties each day. Crew stations for simulation will be the remote control officer and airborne radar technician positions with a growth capability to weapons control officer/intelligence officer for the strike/real-time reconnaissance capability.

C. PROGRAM DATA

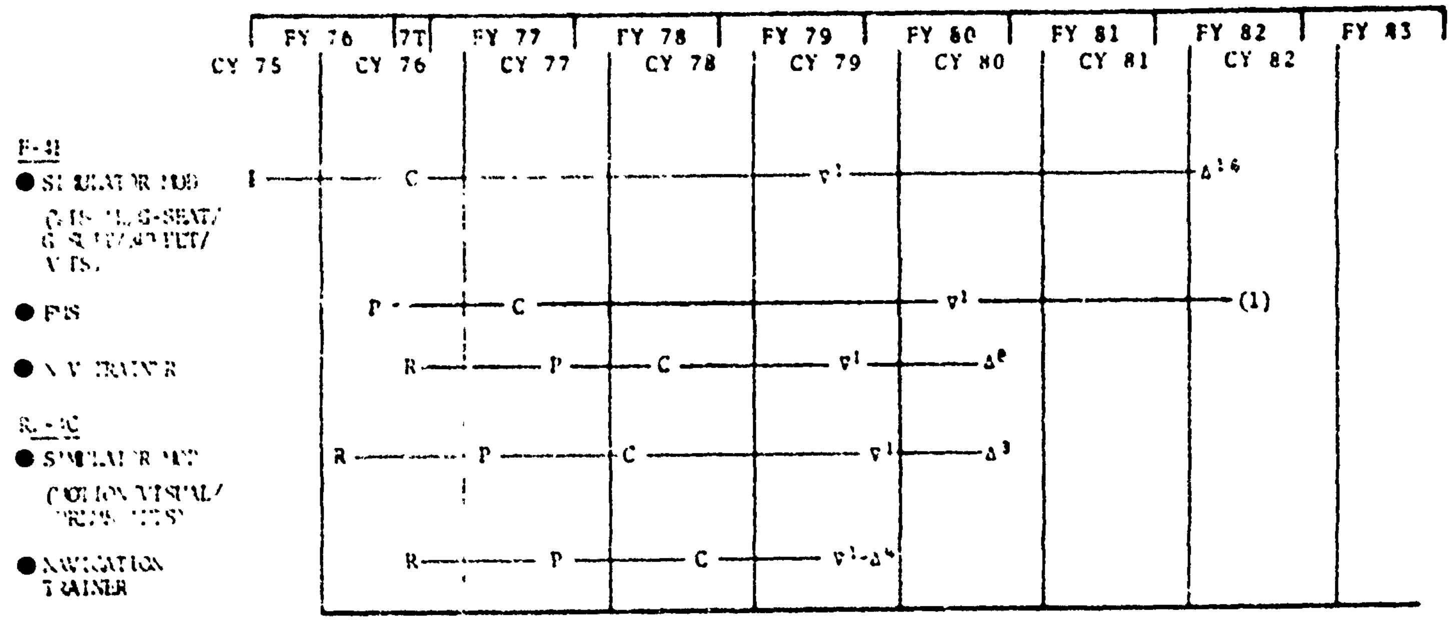
The summary schedule for Future TAC Simulators is shown on Figure VI-1.

D. IMPACT OF NEW CAPABILITIES ON TRAINING PROGRAMS

The estimated change from training operations as they exist in FY 75 versus future operations using the simulators described in paragraph B are presented in Table VI-4.

E. PRIORITIZATION OF NEW CAPABILITIES

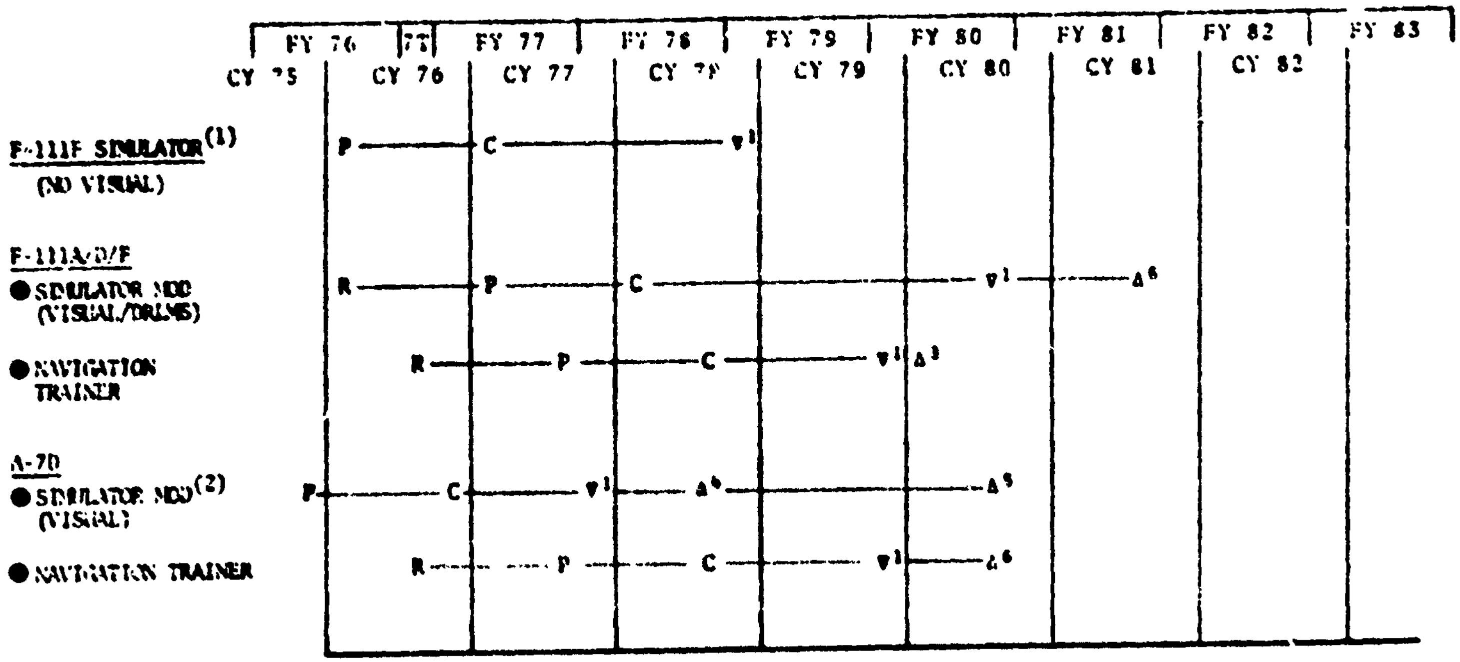
The Tactical Air Command has established a priority listing for the acquisition of weapon system training devices. The listing is in two major groupings.



LEGEND: R = ROC SUBMISSION
P = PMD
C = CONTRACT AWARD

∇ = 1ST DELIVERY READY FOR TRAINING
Δ = LAST DELIVERY READY FOR TRAINING
(1) Δ^{16} FY 85 (32 COCKPITS) TOTAL NUMBER TO BE DETERMINED

FIGURE VI-1. SCHEDULE SUMMARY - FUTURE TAC SIMULATORS

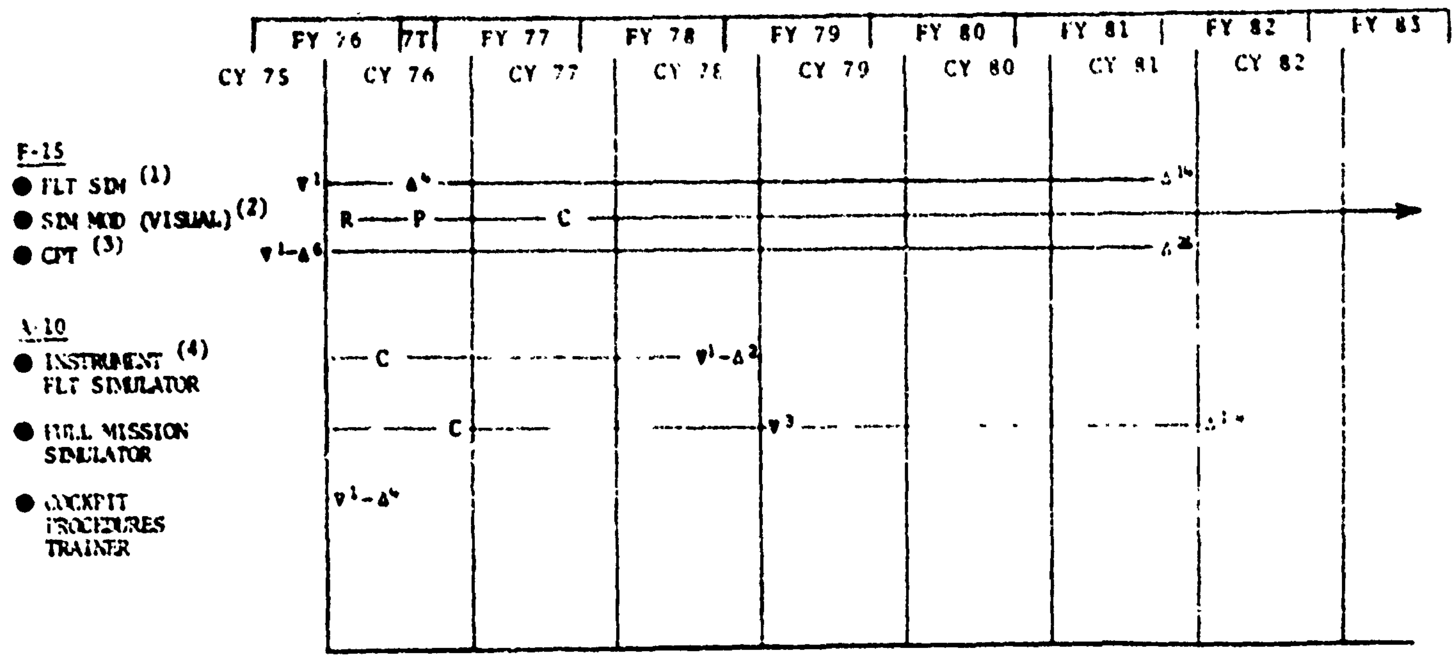


LEGEND
R = ROC SUBMISSION
P = PMD
C = CONTRACT AWARD
∇ = 1ST DELIVERY READY FOR TRAINING
Δ = LAST DELIVERY READY FOR TRAINING

(1) FUTURE PLANS WILL PROVIDE VISUAL AND DRLMS

(2) ROC SUBMITTED APRIL 1972; 4th LIMITED VISUAL FOR ANG, 5th UNIT IS FULL VISUAL.

FIGURE VI-1. SCHEDULE SUMMARY - FUTURE TAC SIMULATORS (CONTINUED)



LEGEND: R = ROC SUBMISSION
P = PMD
C = CONTRACT AWARD
∇ = 1st DELIVERY READY FOR TRAINING
Δ = LAST DELIVERY READY FOR TRAINING

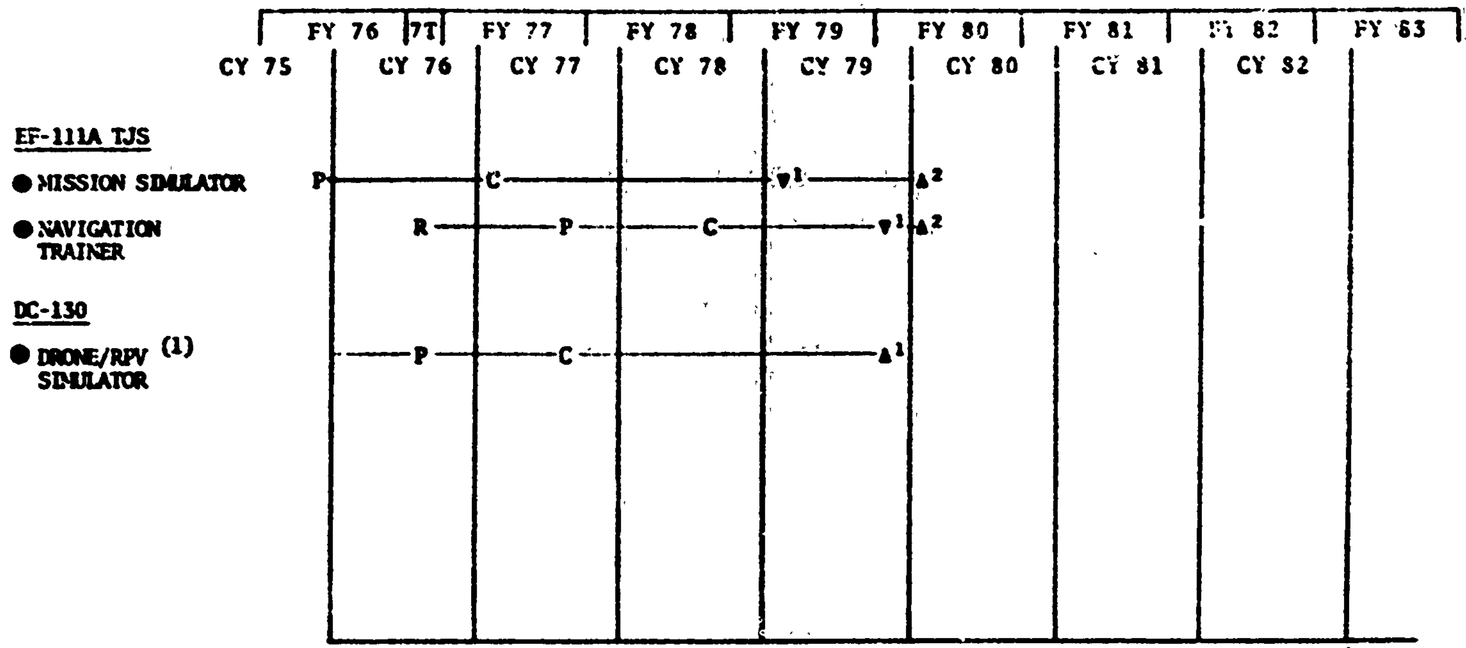
(1) FIRST 4 ITEMS TO BE DELIVERED BETWEEN NOV 75 AND JUL 76. 14 TO BE ACQUIRED.

(2) 14 VISUAL SYSTEMS TO BE ACQUIRED; SCHEDULE UNDETERMINED.

(3) FIRST ITEM DELIVERED APR 75. 6th ITEM TO BE DELIVERED AUG 75. 26 TO BE ACQUIRED.

(4) TO BE UPDATED TO FMS IN FY 80.

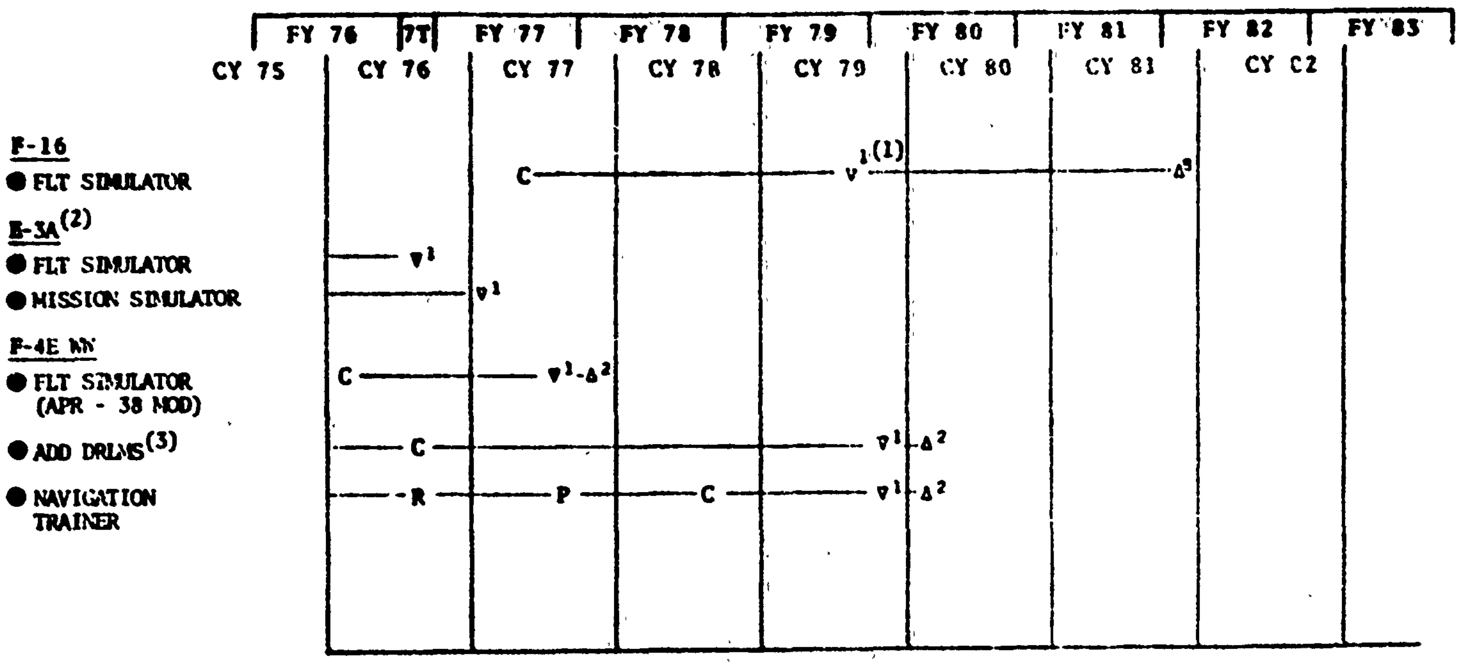
FIGURE VI-1. SCHEDULE SUMMARY - FUTURE TAC SIMULATORS (CONTINUED)



LEGEND: R = ROC SUBMISSION
P = PMD
C = CONTRACT AWARD
∇ = 1ST DELIVERY READY FOR TRAINING
Δ = LAST DELIVERY READY FOR TRAINING

(1) ORIGINAL ROC SUBMITTED SEP 71. SIMULATOR TO BE OWNED BY SAC.

FIGURE VI-1. SCHEDULE SUMMARY - FUTURE TAC SIMULATORS (CONTINUED)



LEGEND:
R = ROC SUBMISSION
P = PMD
C = CONTRACT AWARD
∇ = 1ST DELIVERY READY FOR TRAINING
Δ = LAST DELIVERY READY FOR TRAINING

(1) 2 IFS TO BE UPDATED TO FMS IN FY 84.

(2) E-3A TAC/ADC ROC SUBMITTED SEP 66. MISSION SIMULATOR CONTRACT AWARDED JUL 70. FLIGHT SIMULATOR SUBCONTRACT AWARDED SEP 74.

(3) VISUAL, G-SUIT & AFTS MOD UNDER F-4E PROGRAM.

FIGURE VI-1. SCHEDULE SUMMARY - FUTURE TAC SIMULATORS (CONTINUED)

TABLE VI-4

TAC TRAINING PROGRAM SUMMARY (1)

	CURRENT (2)				PROJECTED (3)			
	TRANSITION		CONTINUATION		TRANSITION		CONTINUATION	
	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME
F-4D/E	32	92	36	228	55-85	60-90	61	192
RF-4C	34	75	36	253	68	40	108	200
F-111A/D/F	44	89	36	264	53-71	62-80	73	216
A-7D	31	80	36	235	52-70	58-76	66	173
AC-130	0	45	0	240	0	45	0	192
F-15 (5)	30-40	90-100	36	216	55-85	60-90	60	190
A-10 (6)	N/A	N/A	N/A	N/A	58-68	68-78	60-84	192-228
F-16 (4)								
E-3A (5) (Flt Sim)	N/A	N/A	N/A	N/A	40-60	30-40	40-60	100-120
F-4E WW (4)								
EF-111A TJS (4)								

(1) EXACT FLYING HOUR REDUCTIONS WILL DEPEND ON THE PROVEN UTILITY OF EACH SIMULATION SYSTEM.
(2) AS OF FY 75.
(3) SIMULATORS DESCRIBED IN PARAGRAPH B.
(4) NOT DEFINED.
(5) CONVERSION COURSE AND ESTIMATED BASIC COURSE.
(6) A-10 PROJECTED DATA BASED ON FULL MISSION SIMULATOR.

1. Buy new training equipment for new weapon systems:

a. A-10 - Instrument Flight Simulators, Dual Cockpit full mission simulators, CPTs, and AETS;

b. F-16 - Mission simulators and CPTs;

c. F-15 - Add visual systems - Awaiting outcome of ASD EDP 2235. (Basic simulators and CPTs are on contract);

d. F-4E Wild Weasel (WW) - Flight simulators, navigation trainers (ROC submitted - APR-38 modification go-ahead given); and

e. EF-111A TJS - Mission simulators, navigation trainers.

2. Buy new simulators or modify existing simulators to support existing TAC weapon system training programs:

a. F-4E - Step 1 - Modify existing to add limited visual system, G-Seat/G-Suit/Buffet, Configuration update and Adaptive Flight Training Systems (AFTS). New navigation trainers. Step 2 - Buy new full mission simulators with motion, wide angle visual, DRLMS, and AFTS. (ROC submitted - Step 1 go-ahead given);

b. F-111A/D/F - Add visual system, DRLMS, configuration update, and AFTS (ROC in process). New navigation trainers;

c. A-7D - Add visual system, DRLMS, configuration update, and AFTS (ROC submitted on visual - awaiting outcome of ASD EDP 2235). New navigation trainers;

d. RF-4C - Add motion, visual system, DRLMS, configuration update, and AFTS (ROC in process);

e. DC-130 - New drone/RPV simulator (old ROC cancelled - new ROC in process);

f. Crew Coordination PTT (ROC being developed); and

g. Air Combat Communications PTT (ROC being developed.

F. ADVANCED SYSTEMS - R&D IMPLICATIONS

TAC requirements for wide angle, high resolution visual systems are related to research now being conducted and planned for near-term implementation in the areas of visual image generation and display (SAAC, ASUPT, F-4 #18, and LAMARS). The Project 1183 DRLMS and high resolution digital data base are being developed primarily in support of the F-111. The digital data base can be also utilized for the F-4, RF-4, A-7 and F-16. Current efforts in the areas of improved instructional capabilities and software design will also benefit all of the TAC programs.

Air-to-Ground Simulator Visual System Engineering Development Program (EDP). There is an urgent requirement to develop a visual system capable of providing ground information for use in simulating air-to-ground (A/G) weapon delivery by tactical aircraft. Visual systems on current R&D simulators either do not provide the information required or provide ground information in such a narrow field of view that questionable A/G simulation is achieved. Three R&D simulators currently available provide the basis for addressing this display problem: the dome/projector unit, used for the Large Amplitude Multipurpose Aerospace Research Simulator (LAMARS); the infinity display/CRT unit, used in the Simulator for Air-to-Air Combat (SAAC), in combination with terrain model board inputs from the F-4E #18 simulator; and the computer generated imagery (CGI), used in the Advanced Simulator for Undergraduate Pilot Training (ASUPT). A joint TAC/AFSC conducted EDP will result in test and evaluation of each visual system to determine candidate A/G visual systems for full mission simulators.

G. TAC MAINTENANCE CONCEPT FOR AIRCREW TRAINING DEVICES

1. Objective

Maximum support of the operational requirements by the Air Force with minimum resources is the objective of the maintenance program. Systems design should enable rapid repair at the organizational level and fast restoration of equipment at the intermediate level. Depot level requirements must be kept at a minimum. This must be achieved by designing maintainability and reliability into the simulator. Adequate documentation must be provided. The simulator must be maintainable at the using unit level by Air Force technicians to allow for maximum utilization. All simulator technicians must be thoroughly trained.

2. Training

A maintenance task analysis is required to identify the complete maintenance training program for each major system; i.e., visual system, modeling, optics, projection, motion, console, operations, computer, etc., to include part task maintenance trainers and training. Training programs will also include technical maintenance data, such as handouts, alignments, operation of equipment, and software update/modification procedures. Sufficient hands-on training must be provided. Type 1 training will be required for simulator operation and maintenance to include development or modification of visual images and the training required to organically perform software/hardware update and control.

3. Technical Data

Technical publications must be maintenance oriented, prepared, numbered, and distributed using the same procedures currently outlined in Air Force directives. Commercial publications are acceptable if approved by the using command. Simple, straight-forward maintenance instructions and formats must be used to enhance maintainability. Publications must contain the information necessary to enable technicians to test, troubleshoot, remove, repair, replace, adjust, and operate the system/components with the tools, test equipment, and spare parts authorized for the appropriate level of maintenance. The technical data must enable fault isolation to the component at each level of maintenance. In addition, the following are software documentation requirements:

a. Detailed data is required to allow the capability for generation or construction of new visual images (hardware or software).

b. Detailed software support documentation must be included to allow the capability for organic software updating. All software routines utilized by the contractor must be provided. All routines and subroutines provided must include complete documentation (i.e., user manuals, program manuals, math models, program narratives, flow diagrams, detail listings, etc.) to be delivered with the simulator.

c. The Air Force is to become the sole manager of the hardware and software configuration and base line data.

4. Supportability

a. Reliability and maintainability must be demonstrated during the first 1000 hours of aircrew utilization. Mean time to repair should not exceed 30 minutes. Continuous operational hours should not accumulate more than 0.2 maintenance hours per hour.

b. Source coding, provisioning, and AGE is required to fault isolate and repair to the bit and piece level. Contractor should provide spares support for a two-year period. This accumulated spares data will provide the basis for future provisioning. Partial provisioning may be required for long lead--high usage items prior to testing and acceptance of the first device.

c. Automatic test equipment should possess the capability for unambiguous fault isolation to include malfunction detection to the module, chassis wiring or chassis mounted component level. To achieve this end, self-test programs must be supplemented with technical data of sufficient range and depth to test loop diagrams in the test procedure. Maximum use of self-calibrating circuitry should be incorporated. The use of proprietary equipment, software or designs must be avoided through the judicious design of the device.

d. The complexity of the maintenance and supply tasks should be minimized by the use of simple design which includes optimum interchangeability; e.g., circuit cards, and use of standardized equipment which meets or exceeds specification requirements.

e. The design must provide for rapid and positive recognition of equipment malfunction or marginal performance. It must also provide for rapid and positive idenfification of the replaceable defective part/assembly or component and provide for minimum numbers and types of tools and test equipment required to perform maintenance.

f. Requirements for soldering should be reduced by the use of plug-in circuits/components. Special tools or equipment must be held to an absolute minimum. Removal of one accessory component should not require removal of others to facilitate accessibility.

g. Scheduled calibration and alignment requirements for the system or its components should be obviated through maximum use of self-calibrating circuitry.

5. Inspection Requirements

The simulator should be designed toward a goal of no scheduled inspections for electronics or performance characteristics. The areas shall be checked through automated test and calibration programs. Automated routines should be provided that perform Daily Readiness, Performance Evaluation and Simulator Calibration Checks. Daily Readiness Checks are used to ensure complete systems operation prior to daily operations. These are designed to quickly ascertain subsystem operations and must not exceed a total of 15 minutes. Performance Evaluation Checks are designed to exercise the total simulator system and subsystems (i.e., input/output devices, computers, motion, etc.). These programs are intended as an in-depth check, as required, to ascertain total systems performance. Calibration checks are designed to ensure correct subsystems operation conditions under program control using known inputs. Time limitations for Performance Evaluation and Calibration Checks should not exceed two hours and should be on an as-required basis. These programs should be designed to operate with minimum operator intervention and once started will sequence under computer control. However, the program should be designed to check functional areas independently. This does not negate the requirement for inspections of hydraulics, mechanics, etc. Any of these scheduled inspections should not require more than one-half hour to accomplish with a crew of two five-level specialists.

6. Operational Flight Program Update Capability

If any on-board computers are used in the aircraft, the simulator must have the capability to be updated in approximately the same amount of time as that required for changing the aircraft computer program itself.

7. Stabilized Power Requirement

The device must be designed to be compatible with the utility and support systems normally encountered at an Air Force installation. Unusual device requirements will be avoided through judicious design of the hardware.

Where they cannot be avoided, peripheral equipment will be provided with the device to satisfy the requirements. For example, ordinary commercial power is normally supplied to flight simulators on Air Force installations. While voltage and frequency are normally held within fairly close tolerance, this does not preclude momentary power interruptions and transients on the circuitry due to lightning and other external disturbances. If the device is sensitive to these conditions, the device must have the capability to:

a. Filter input spikes so no equipment damage shall occur, and

b. Protect itself through such programs as core memory save features and auto restart procedures.

SECTION VII

MILITARY AIRLIFT COMMAND (MAC)

A. GENERAL

1. Command Philosophy

ISD studies have identified numerous synthetic training devices which are essential if our training programs are to progress toward our desired goal of efficient individualized training. MAC must acquire synthetic training devices capable of "bridging the gap" from inanimate mockups and familiarization trainers to the complex and comparatively expensive simulators with dynamic system response and full system interface. A fully individualized program that progresses from simple to complex with training devices early in the program will enhance learning and retention.

a. Factors: Numerous factors and events have been the cause of our ever increasing requirement for synthetic training devices.

(1) ISD methodology identifies requirements for a family of devices to provide training in the least cost device capable of providing the training prior to progressing to more costly media.

(2) The crew ratio has experienced large fluctuations which have resulted in an overall increase in teaching requirements during the build-up phase.

(3) Entry skill and grade criteria for enlisted crew members have been reduced to broaden the recruiting base.

(4) Centralized training now includes copilot, AC/IP upgrade, navigator training, loadmaster training, inflight refueling in the C-5 and MAC training in the C-141.

(5) Visual systems greatly increase the training capability which increases the synthetic training tasks.

(6) The energy crisis demands greater attention to fuel conservation.

(7) MAC presently trains all rendezvous tasks associated with inflight refueling in the C-5 simulator and is exploring methods of adding a tanker model to the visual system to provide more pilot training. Future plans include inflight refueling for the C-141.

(8) Technology has steadily improved the fidelity for simulator hardware and computer software. This has resulted in the increased capability to transfer aircraft training tasks to the simulator.

(9) Increased aircraft acquisition and operating costs highlight the inherent economy and efficiency of synthetic training.

(10) Prohibited training maneuvers that cannot be accomplished in the aircraft increase synthetic training time requirements.

b. Flying Hours Reductions: Any flying hour reductions achieved through the use of simulation will result from efficiently programmed training systems that make maximum use of these devices. Since neither the training value of specific devices nor the effects of the integration of several devices into a training program can be accurately estimated, future projected savings must be used with caution. These projections are subject to periodic revision as new knowledge and operational efficiency is gained. Forecast reductions are based on the following assumptions:

(1) All hardware requirements will be met. The MAC plan is for development of a complete instructional system with interdependent parts.

(2) Continuation of the ongoing ISD efforts and initiation of a C-9 ISD effort will be supported with adequate manpower and funds.

(3) MAC and Air Force Regulations will be changed to allow more currency and evaluation requirements to be accomplished in the simulator.

(4) Actual mission flying will be sufficient to maintain pilot proficiency. If the day-to-day requirement for airlift and rescue sorties is significantly

reduced, there will not be enough simulator time available to allow proficiency to be maintained in the simulator. Any reduction in mission flying or any increase in proficiency requirements will cause more simulators to be needed.

(5) The number of crews will remain at or below presently projected levels for each weapon system. An increase in the number of assigned crews would cause a corresponding requirement for additional synthetic training devices.

(6) Crew member performance requirements will remain essentially unchanged. Should crew members be required to become proficient in additional skills, planned numbers of simulators may not be sufficient to accomplish required training.

(7) Currency requirements will remain essentially the same as currently established.

2. Formal Aircrew Training Programs

Formal transition training syllabi have been established for MAC aircraft as shown in Table VII-1.

3. ISD Activities

Military Airlift Command initiated Instructional System Development (ISD) projects for its flying training programs in February 1972. By using ISD methods, the Command has already achieved significant flying time reduction in its formal aircrew training syllabi. A summary of these savings is shown in Table VII-2. The percentage figures refer to percent change in pre-ISD flying hours devoted to initial and continuation training.

Initial ISD efforts were oriented toward particular crew positions. Studies now in progress and planned for the future will be oriented toward weapon system crews. The Command views ISD as a continuing effort through which efficient and effective training can be achieved.

B. TRAINING DEVICE STATUS AND REQUIREMENTS

Simulators and training devices now owned by MAC are being utilized to the maximum extent possible in accordance with performance characteristics, maintenance requirements and training requirements.

TABLE VII-1

MAC FORMAL TRANSITION AIRCREW TRAINING

AIRCRAFT	CREW POSITIONS	CREWS/YEAR	LOCATION OF FORMAL TRAINING
C-5A	PILOT, NAVIGATOR FLIGHT ENGINEER LOADMASTER	112/70*	ALTUS AFB OK
C-141A	PILOT, NAVIGATOR FLIGHT ENGINEER LOADMASTER	245/245*	ALTUS AFB OK
CH-3	PILOT, PARARESCUE FLIGHT MECHANIC	36/28*	KIRTLAND AFB NM
HH-53	PILOT, PARARESCUE FLIGHT MECHANIC	38/30*	KIRTLAND AFB NM
UH-1	PILOT, PARARESCUE	48/48*	KIRTLAND AFB NM
TH-1F	PILOT	31/31*	KIRTLAND AFB NM
C-130	PILOT, NAVIGATOR FLIGHT ENGINEER LOADMASTER	307/307*	LITTLE ROCK AFB AR
HC-130	PILOT, NAVIGATOR FLIGHT ENGINEER RADIO OPERATOR LOADMASTER	24/18*	HILL AFB UT
C-9	PILOT	18/18*	LONG BEACH CA (FLIGHT SAFETY INC.)
T-39	PILOT	8**/250***	ST. LOUIS MO (FLIGHT SAFETY INC.)

* FY 1976 AND BEYOND BASED UPON THE CREW POSITION WITH HIGHEST TRAINING REQUIREMENT.

** TEST CLASS LAST QUARTER FY 1975.

*** PROPOSED PENDING OUTCOME OF TEST CLASS.

TABLE VII-2

IMPACT OF ISD

AIRCRAFT	FLYING HOUR REDUCTIONS HRS	(%)	FUEL SAVED (MILLIONS GALS/YR)
C-5	1,792	(36.9)	6.16
C-141	5,615	(10.8)	12.27
UH-1	333	(18.8)	0.02
CH-3	1,190.4	(16.6)	0.21
HH-53	1,6[illegible]4.8	(22.7)	0.47
TOTAL	10,585.2	(14.5)	19.13

1. <u>Airlift Aircraft</u>

a. <u>C-5/C-141 Visual System (Altus)</u>

A contract option to provide additional limited visual capability for the Altus AFB simulators was exercised in March 1974 and completed in April 1975. This system is the same as is now shared by one C-141 and one C-5 simulator at Altus AFB, Oklahoma. It consists of one model board image generation system and two visual displays. This modification is expected to enable MAC to continue to realize significant reductions in flying time for C-5 and C-141 aircrews in formal training, as documented in MAC Operational Test and Evaluation Report 5-10-73, C-5/C-141 Limited Visual System November 1974.

b. C-141/C-5 Cockpit Procedures Trainers

(MAC ROC 21-70, PMD R-Q4-42 and MAC ROC 2-73, PMD R-Q4-54)

Seven C-141 CPTs (MAC ROC 21-70) are planned with two going to Altus AFB and five going to airlift wings. The three C-5 CPTs (MAC ROC 2-73) will go to Altus, Dover and Travis, respectively. Both Command ROCs were originally validated by USAF and budgeted for FY 1975. They were both returned for revalidation due to changed requirements and resulting increased cost estimates. During subsequent reviews by CSAF RRG, one C-5 CPT without navigator capability was approved for Altus AFB. The C-141 ROC was deferred pending resolution of the impact of the Inertial Navigation System (INS) modification to the aircraft reclama data provided during April 1975. MAC requires the capability to provide hands-on procedures training in preparation for the mission flight simulator and flight training. This training should include selected functions from the Before Engine Start Checklist through the Before Leaving the Aircraft Checklist. MAC recommends that the CPTs be designed to the "best commercial standards" and have systems capabilities similar to the DC-10-L1011 and 747 CPTs used by the airlines. In addition, a navigator station is required for three of the C-141 CPTs and a training device which provides independent satellite navigator station operation is required for the C-5 simulator. These devices will provide low cost readiness training for pilots, flight engineers, and navigators. Time spent in these devices will prepare crew members to more effectively use mission flight simulators thus freeing the more complex devices for tasks which optimally utilize their unique simulation capabilities. CPTs will provide engine run training for maintenance personnel, engineer preflight training, navigator training, and normal and emergency procedures practices for the entire crew. Crew members can train separately (each crew station can be separated electronically and physically) or they can train as a crew. Electronic separation would have the additional benefit of allowing integration of a portion of the crew while other crew members receive individual training. Normal and emergency procedures can be practiced at regular intervals and can be certified as satisfactory before using the simulator.

c. <u>Limited Visual Systems for C-5 and C-141 Flight Simulators Assigned to Airlift Wings</u> (MAC ROC 5-73, PMD R-Q-5093-(1)

This modification will provide limited visual systems for three cockpit visual display systems at Travis AFB (one C-141 and two C-5s). One complete C-5 flight simulator visual system is to be installed at Dover AFB. McGuire, Charleston, McChord and Norton AFB will each receive one complete C-141 flight simulator visual system. This modification will allow training which requires a more complete set of visual cues to be accomplished in the simulators. The visual system is expected to increase the synthetic training value of existing simulators, improve efficiency, and reduce the cost of flying training. Annual continuation and upgrade training are forecast to decrease by about four hours per C-5 pilot and by about four hours per C-141 pilot when these systems become operational. The low technological risk of these devices and short lead time for delivery can result in early benefits even for the limited system. The potential pay payoff is large in comparison to the acquisition cost.

d. <u>C-141 Mission Flight Simulators (Draft ROC)</u>

MAC does not have adequate simulation devices to train C-141 aircrews within the projected flying hour restrictions imposed by fuel conservation and the high cost of flying training. The recommended solution is to procure six state-of-the-art mission flight simulators to complement the existing 8 flight simulators. One each simulator will be located at Altus AFB, Charleston AFB, McChord AFB, Norton AFB, and Travis AFB. The mission flight simulators should have the following capabilities:

(1) Six-degrees-of-motion,

(2) Pilot, copilot, flight engineer, instructors, and observer stations,

(3) Exact simulation of the cockpit,

(4) Radar (weather) simulation, and

(5) A day and night color visual display of at least 120 degrees horizontal and +10 degrees -15 degrees vertical.

The visual scene depicted must represent an airport complex and adequate terrain to perform straight-in and circling instrument approaches and visual approaches. The present C-141 flight simulators are pilot/flight engineer only devices with three degrees-of-freedom systems and no visual systems. They represent early 1960 technology. The eight simulators are used to capacity and additional simulator time is not available to further reduce aircraft flying time. MAC requires the additional new C-141 mission flight simulators to complement the existing and proposed simulation devices. The most economical mix of simulation devices as determined by the principles of Instructional Systems Development include Part Task Trainers, Cockpit Procedures Trainers, flight simulators and mission flight simulators. The existing C-141 simulators when upgraded by addition of visual devices under MAC ROC 5-73 will satisfy the flight simulator requirement. Cockpit Procedures Trainers have been requested under MOC ROC 21-70 and will have integrated and stand alone capability. The new mission flight simulators will be used to complete the instructional system for the C-141. These devices will be used for initial qualification and upgrade training conducted at Altus AFB OK and refresher and continuation at all units. These mission flight simulators will form the top tier in the hierarchy of simulation devices as envisioned by the principles of ISD and will substantially reduce the aircraft flying hours required for aircrew training.

e. C-130 Mission Flight Simulator/CPT (MAC ROC 22-71/TAC ROC 16-71)

Ten C-130 mission simulators and two cockpit procedures trainers are to be installed at the following bases: Little Rock AFB - 5, Dyess AFB - 1, Pope AFB - 1, McChord AFB - 1, Hill AFB - 1. PACAF will also receive one mission simulator. Two cockpit procedures trainers will be installed at Little Rock AFB. This changes the TAC simulator requirements as specified in TAC ROC 16-71 from nine simulators to two cockpit procedures trainers and ten mission simulators. MAC ROC 22-71 calls for the procurement of state-of-the-art equipment and will not involve research and development. In addition to providing better and safer training for C-130 crews, this device is expected to yield savings in fuel and O&M cost both in initial and continuation training. The simulators will have the capabilities of six degrees of freedom motion base and visual. It will include pilot, copilot, flight engineer, navigator and instructor positions. The cockpit procedures trainer will contain pilot, copilot and flight engineer positions and will be capable of all normal and emergency procedures training to include all inflight malfunctions. The cockpit procedures trainers need not contain motion or visual systems.

f. C-5 Flight Mission Simulators

MAC has a deficiency in present motion systems because it is not possible to teach rudder control in the flight simulator. Due to near centerline thrust trainers, the UPT graduate is not adequately trained in the use of rudders. In addition to normal maneuvering, MAC requires rudder control proficiency in maneuvers involving asymmetric thrust, asymmetric flight controls, dutch roll and cross winds. The absence of lateral translations (slip and skid cues) tend to cause overcontrol of the rudder when operating with the limited visual system because the trainee must wait for the results of a small correction to appear as visual body rate change rather than feeling the result of a small correction first. Consequently, the trainee often puts in the second or a larger correction before the visual body rate change is perceived. The result is small but continuous overshoots that appear as divergent aircraft stability to the trainee. A six degree of freedom motion base will provide a rudder training capability in the flight simulator. Six degree systems are preferred because of extensive commercial design and use experience in similar aircraft simulation systems such as 747 and 707. MAC has experience with six degree systems on the H-3/H-53 simulators. The systems are found to be realistic and easily maintainable. Any lesser degree of freedom motion system would require extensive test in similar type aircraft simulation systems. MAC is currently studying the possibility of providing C-5 pilots with six degree freedom of motion and expanded visual systems during initial, refresher and proficiency simulator training. MAC will require three additional simulators to provide adequate simulation devices to train C-5 aircrew if the projected flying hour programs are reduced. Two methods of providing six degree motion and expanded visual systems plus the additional hours to help compensate for reductions in the projected flying hours are:

(1) Modification of the present simulator which would entail replacement of present motion and visual systems including extensive facilities modification. This method will not increase trainer availability.

(2) Acquisition of a pilot task trainer that incorporates six degree motion and expanded visual system. Since system and procedures training are available in the present simulators complex systems such as circuitry logic, navigational systems (IDNE) and MADAR devices need not be included. This method increases trainer availability and continues to use present devices as mission flight simulators in a total program. Either of the two methods will require installation of one device at each of three locations; Altus, Travis and Dover.

2. Rescue Aircraft

a. CH-3/H-53 Flight Simulator Visual System (MAC ROC 1-73)

MAC has two helicopter flight simulators to train Aerospace Rescue and Recovery Service (ARRS) CH-3 and HH-53 crews. These simulators incorporate state-of-the-art technology except that no visual systems have been provided. The fact that ARRS helicopter operations are largely conducted in conditions of visual contact with the ground makes the addition of visual systems a potentially great improvement to the training effectiveness of these devices. The Air Staff Board Simulator Panel recommended coordination to view systems used by other services.

b. CH-3/HH-53 Cockpit Procedures Trainers

The acquisition of one CH-3 CPT and one HH-53 CPT which incorporate full instrumentation and working indicators will allow procedural training now conducted in aircraft to be performed in simulators. It is expected to allow extensive reductions in flying time necessary for both initial transition training and annual continuation and upgrade training for CH-3 and HH-53 pilots. The extent of the reduction possible will depend on both the fidelity of simulation and on changes to existing regulations.

c. H-1 Helicopter Simulator

MAC requires a simulator that will represent the characteristics of the UH-1N twin engine helicopter. Requirements are similar to those of CH-3/HH-53 simulators and visual system except that aerial refueling capabilities are not required. This device will be used in the initial qualification training in Air Force models of the H-1 provided to graduates of the US Army Helicopter Training Course, and in the conversion training for Air Force fixed wing pilots transitioning into rotary wing aircraft. The device will be operated by the 1550th Aircrew Training and Test Wing at Kirtland AFB, NM.

3. Aeromedical Evacuation Aircraft

a. C-9 Simulator/CPT (MAC ROC 7-74)

All C-9 aircrew training is now provided by civilian contractors. The Air Force does not have the capability to adequately train C-9 aircrews, particularly within the austere flying hour budget. The MAC has a requirement for a C-9 Mission Flight Simulator and Cockpit Procedures Trainer (CPT) to be readily available to all C-9 aircrews. The simulator should duplicate the cockpit of the C-9, have a six degree of motion system and a day and night visual system. The CPT would duplicate the cockpit and have limited system response. The simulator and CPT would be installed at the location where the greatest number of C-9 pilots are based, i.e., Scott AFB, IL. The simulator and CPT will be used both in transition and continuation training for pilots. Pilots now get initial simulator training and 20 hours per year of refresher simulator training from commercial sources. Under the expanded use of simulators, the pilots will get their initial training, upgrade training, flight evaluation, and up to 36 hours per year of refresher training in the simulator. Instrument and proficiency evaluations will be given in the simulator. A transition training unit (TTU) would be established to conduct all ground and flight training required for initial qualification, aircraft commander upgrade and instructor/flight examiner upgrade. To provide this training the simulator should have the following capabilities:

(1) Six degrees of motion,

(2) Pilot, copilot, instructor and observer stations,

(3) Exact simulation of the cockpit,

(4) Radar (weather) simulation, and

(5) A day and night color visual display of at least 60 degrees and possibly 120 degrees horizontal and +10-15 degrees vertical. The visual scene depicted must represent the airport complex and adequate terrain to perform straight-in and circling instrument and visual approaches. The need for a C-9 CPT has been determined although an instructional system development (ISD) program has not been initiated in the C-9 weapon system. Acquisition of the training devices concurrent with the ISD program could provide a training capability as much as 30 months (minimum acquisition cycle predicted to date) sooner than waiting for completion of the ISD program. MAC advocates an organic capability for C-9 simulator training as being the solution for effective C-9 aircrew training.

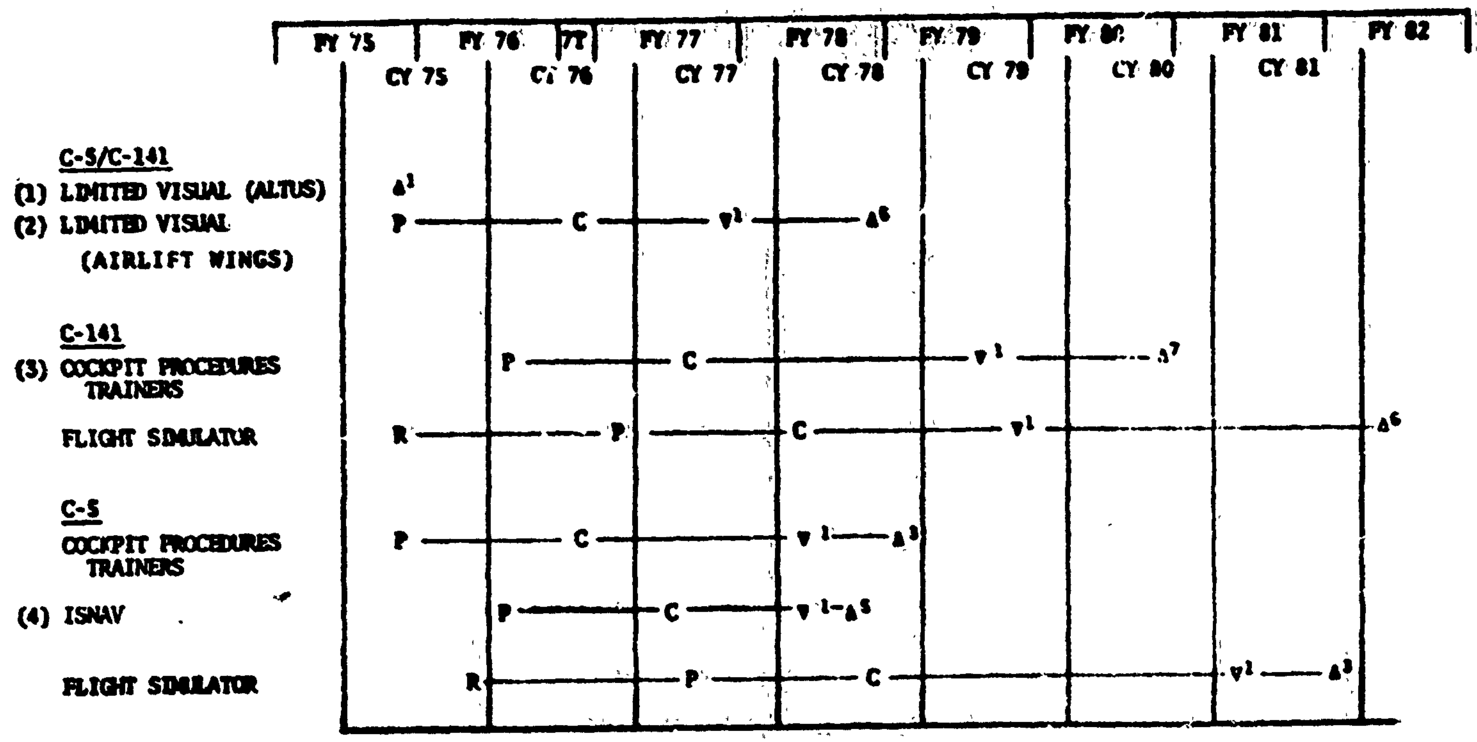
4. Weather Aircraft

a. C-135 Visual Systems (Draft ROC)

MAC requires a visual system for installation on the C-135B simulator located at McClellan AFB, CA. Addition of a visual capability will increase the synthetic training value of the simulator, improve efficiency and reduce cost of flight training. Visual capability on the simulators will allow much of the takeoff and landing practice now done in the aircraft, to be accomplished in the simulator. The visual system must be capable of providing out-the-cockpit-window training for visual takeoff, approach, landing and taxiing, along with transition from instrument to visual flight operation. Simulated operation in adjustable weather visibility, range, ceiling, and controllable dusk and dark conditions must be possible. This capability is required for the pilot, copilot, and instructor pilot positions. The visual scene depicted must represent an established airfield with dual runways, one of which must have a standard airfield lighting system. The C-135B simulator presently in use has a three-degree-of-freedom motion system, a digital/analog computer, stations for pilot, copilot, flight engineer and instructor. The addition of the visual system is expected to reduce flying hours expended on training by 4 hours per pilot.

C. PROGRAM DATA

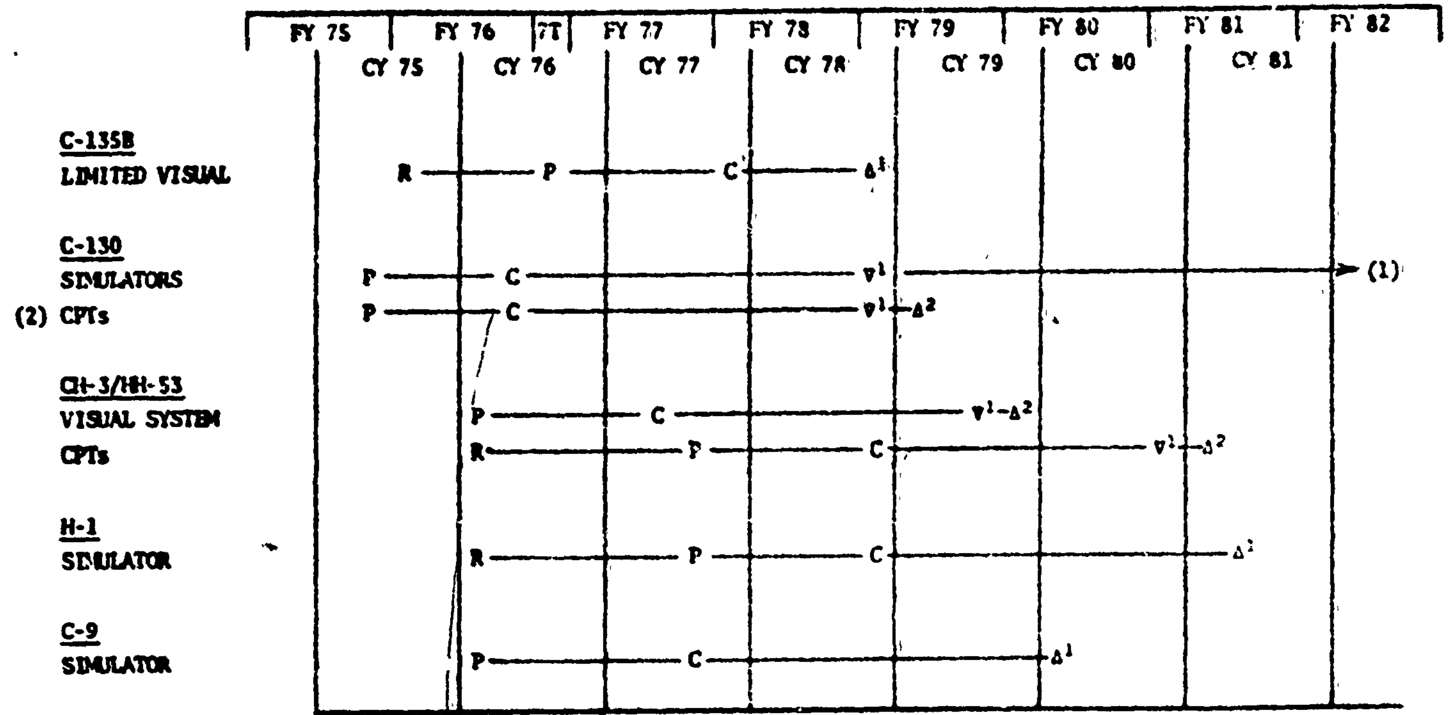
Figure VII-1 is the Planning Schedule for future MAC Simulators.



LEGEND: R = ROC ISSUED
P = PMD
C = CONTRACT INITIATED
∇ = 1st DELIVERY
Δ = LAST DELIVERY

(1) COMPLETED APR 75, 1-MODEL BOARD & DISPLAYS FOR C-5/C-141 ADDED TO EXISTING COMPLEX AT ALTUS.
(2) TRAVIS SYSTEM INCLUDES VISUAL DISPLAYS FOR 3 COCKPITS (2 C-5/1 C-141) AND 1 CAMERA MODEL BOARD IMAGE GENERATION SYSTEM TO BE TIME SHARED. THE 5 REMAINING SYSTEMS CONSIST OF A DISPLAY AND IMAGE GENERATION SYSTEM FOR 1 C-5/4 C-141 SIMULATORS AT SEPARATE BASES.
(3) ANTICIPATE OPTION ON CONTRACT FOR INITIAL CPT(s) AT ALTUS AFB FOR ADDITIONAL TRAINERS FOR AIRLIFT WINGS.
(4) INDEPENDENT SEPARATED NAVIGATOR STATIONS FOR USE WITH C-5 FLIGHT SIMULATORS.

FIGURE VII-1. MAC PLANNING SCHEDULE



(1) Δ^{10} 4TH QUARTER FY 82.

(2) SCHEDULE BASED ON FOLLOW-ON TO TAC C-130E PROGRAM.

FIGURE VII-1. MAC PLANNING SCHEDULE (CONTINUED)

D. IMPACT OF NEW CAPABILITIES ON TRAINING PROGRAMS

Plans for employment of those devices identified in paragraph B forecast substantial increment reductions in aircraft operation for training purposes as new devices are introduced into MAC's instructional systems. Table VII-3 shows only the forecast change from training operations as they existed on 31 October 1973 to operations as they are projected upon provision of all required capabilities. Table VII-4 indicates the estimated impact on flying training accruing to each of the training devices discussed previously. It should be emphasized that these figures are for planning purposes and actual reductions will be the product of successful integration of the devices into the MAC training program. A summary of MAC ROC activity is provided in Table VII-5 together with the required quantity and planned location of the facilities.

E. COMMAND PRIORITIZATION OF NEW CAPABILITIES

MAC/DOTO 222050Z Feb 74, Air Force Master Plan - Simulators for Aircrew Training is the source document of this information. Due to the interdependency of the individual devices in a total training system, it is not possible to adequately prioritize requirements based strictly on projected savings. For example, the procurement of visual systems will not allow an appropriate reduction of flying hours until an additional device (CPT or additional simulator) is provided to free the presently fully utilized simulator for additional visual training. Devices are prioritized within categories 1 through 4 below.

1. Near term delivery of validated and identified ROCs (Item a through d have been partially funded for FY 75):

a. Limited visual systems for airlift units (ROC 5-73),

b. Ten C-130 simulators and two CPTs (MAC ROC 22-71/TAC ROC 16-71),

c. Visual system for helicopter simulators (MAC ROC 1-73), and

TABLE VII-3

MAC NON REVENUE TRAINING SUMMARY
(NON-REVENUE TRAINING HOURS PER PILOT TRAINED)

	CURRENT (1)				PROJECTED (2)			
	TRANSITION (3)		CONTINUATION (4)		TRANSITION (3)		CONTINUATION (4)	
	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME
C-5	22.5	14.0	14.0	22.0	36.0	2.5	20.0	10.0
C-141	22.5	15.0	8.0	22.0	42.0	2.5	20.0	10.0
H-1	0	72.5	0	50.0	36.5	36.0	[illegible]	40.0
CH-3	25.5	43.5	7.5	47.0	51.0	18.0	50.0	33.0
HH-53	25.5	45.0	7.5	47.0	51.0	19.5	30.0	33.0
HC-130	0	38.0	8.0	95.0	13.0	19.0	22.0	30.0
C-130	17.0	37.5	12.0	52.6	20.0	21.0	22.0	26.5
C-9	10.0	12.0	8.0	6.0	16.0	4.0	[illegible]	2.0

(1) AS OF 30 JUNE 1975.
(2) WHEN ALL PLANNED MODIFICATIONS AND NEW PROCUREMENTS OF TRAINING DEVICES HAVE BEEN IMPLEMENTED INTO THE TRAINING PROGRAM.
(3) PER PILOT, SINCE OTHER DEVICES PRIMARILY AFFECT THE AVAILABILITY OF TRAINING DEVICES FOR PILOT USE.
(4) HOURS PER PILOT PER YEAR.

TABLE VII-4

ESTIMATED FLIGHT TIME REDUCTIONS DUE TO SIMULATORS

ROC NUMBER	TITLE	TRANSITION FLIGHT TIME	CONTINUATION FLIGHT TIME
21-70	C-141 COCKPIT PROCEDURES TRAINER	2	4
7-71	C-141/C-5 VISUAL SYSTEM (ALTUS)	3/3*	-
22-71	C-130/HC-130 SIMULATOR/CPT	16.5/19	26/65
1-73	H-3/HH-53 VISUAL SYSTEM (HILL)	25.5/25.5**	14/14
2-73	C-5 COCKPIT PROCEDURES TRAINER	2	4
5-73	C-141/C-5 LIMITED VISUAL SYSTEM (AIRLIFT WINGS)	-	4/4
7-74	C-9 SIMULATOR/CPT	8	4
DRAFT	C-135B VISUAL SYSTEM	-	4***
DRAFT	C-141 SIMULATOR	10.5	4

* AS A RESULT OF VISUAL SYSTEM AT ALTUS, TRANSITION FLIGHT TIME FOR THE C-5 WENT FROM 17.0 TO 14.0 AND FOR THE C-141 FROM 18.0 TO 15.0.

** WITH THE ADVENT OF SIMULATORS AT HILL FOR THE H-3 AND H-53 PROGRAM, FLIGHT TIME DECREASED FROM 88 HOURS IN BOTH COURSES TO 43.5 IN THE H-3 AND 51.0 IN THE H-53. BOTH COURSES NOW REQUIRE 22.5 HOURS IN THE SIMULATOR. THE VISUAL SYSTEM WILL FURTHER REDUCE REQUIREMENT TO 28 PER COURSE.

*** AIRCREWS ROTATE THROUGH McCLELLAN AFB FOR REFRESHER TRAINING; SIMULATOR WILL BE USED FOR INITIAL AND REFRESHER TRAINING.

TABLE VII-5

SUMMARY - MAC ROC ACTIVITY

ROC NUMBER	TITLE	SUBMITTAL DATE	QUANTITY	ANTICIPATED RMD	BASE
21-70	C-141 COCKPIT PROCEDURES TRAINERS	12 OCT 70	7	16 JAN 74* R-Q 4-42	2 ALTUS 1 EA AIRLIFT WING
[illegible]	C-141/C-5 VISUAL SYSTEM (ALTUS)	30 MAR 71	2	23 MAR 72** R-Q 2373	2 ALTUS (COMPLETE)
22-71	C-130 SIMULATOR/CPT	23 SEP 71	10/2	19 JUN 72 R-Q 2-141	5/2 LITTLE ROCK, 1 HILL, 1 POPE, 1 DYESS, 1 McCHORD 1 PACAF
1-73	[illegible]-3/HH-53 VISUAL SYSTEM (HILL)	21 APR 73	2	16 NOV 73 R-Q 4-033	2 HILL
2-73	C-5 COCKPIT PROCEDURES TRAINERS	30 MAR 73	3	16 JAN 74*** R-Q 4-54	1 ALTUS 1 DOVER, 1 TRAVIS
5-73	C-141/C-5 LIMITED VISUAL SYSTEM (AIRLIFT WGS)	27 AUG 73	8	14 MAR 74 R-Q 4-54	1 DOVER, 3 TRAVIS 1 McGUIRE, 1 McCHORD 1 N..TON, 1 CHARLESTON
[illegible]	C-9 SIMULATOR/CPT	24 JUL 74	1	JUL 75	1 SCOTT
DRAFT	C-135B VISUAL SYSTEM	JUN 75	1	FEB 76	1 McCLELLAN
DRAFT	C-141 SIMULATOR	JUN 75	6	JAN 77	1 EA AIRLIFT WG
STUDY	C-5 SIMULATOR	JAN 76	3	JUN 77	1 ALTUS, 1 TRAVIS, 1 DOVER

* ORIGINALLY VALIDATED BY AIR FORCE AND BUDGETED FOR FY 1975, RETURNED FOR REVALIDATION PENDING APPROVAL OF INS.

** COMPLETED 31 MARCH 1975.

*** ORIGINALLY VALIDATED BY AIR FORC AND BUDGETED FOR FY 1975, RETURNED FOR REVALIDATION OF COST ESTIMATES.

d. Cockpit Procedures Trainers: MAC ROC 2-73 (C-5) and MAC ROC 21-70 (C-141) as amended June 1974 requested CPTs for Altus and each airlift unit to free the simulators for optimum visual and full mission simulation. (CSAF/RRG approved one C-5 CPT for Altus in January 1975, reclama data has been submitted).

2. Equipment required to provide increased training capabilities:

a. Six additional C-141 simulators (Draft ROC),

b. C-5 simulator (Planning Stage),

c. Cockpit procedures trainers for H-3/HH-53, and

d. One C-135 simulator visual system (Draft ROC).

3. Equipment with relatively low operating cost savings potential or fuel savings, but having the potential for improved safety:

a. One H-1 simulator, and

b. One C-9 simulator.

SECTION VIII

STRATEGIC AIR COMMAND (SAC)

A. GENERAL

1. Command Philosophy of Training

SAC, as a specified command, has an overall mission to deter aggression by developing and maintaining a viable, responsive, nuclear retaliatory force. This force is composed of operationably ready weapon systems, each designed to satisfy a particular Emergency War Order (EWO) objective. Since successful deterrence is based upon demonstrable credibility of the weapon system and because the key to weapon system integrity rests with the man/machine interface (the sum total of vehicular and crew performance), an untrained crew member compromises the integrity of the entire weapon system.

Within SAC, operations crews are managed as organic subsystems subordinate to the total weapons system. It is the responsibility of the Operations and Training Directorate to prepare the "organic subsystem" for performance in combat. The training concept is divided into three academic phases of development: initial qualification, mission qualification, and continuation combat crew training.

Initial qualification of aircrews consists of transition training into the actual aircraft in which the crew is to become qualified. It occurs subsequent to undergraduate training (generally conducted by the Air Training Command), with crew resources obtained directly from undergraduate school or some other weapon system. In addition, SAC performs undergraduate training for drone launch controllers, boom operators, and gunners.

The initial qualification phase, commonly referred to as Combat Crew Training (CCT), consists of the application of discrete behavioral disciplines in adapting the specialities learned in the first phase to a specific weapon system. Similar to the specialty qualification phase, the CCT phase enjoys weapon system commonality and, therefore, stability of the training syllabus. The training strategy employed consists of first defining the objectives of the CCT phase of training and then working back through ISD (Instructional System Development, AFM 50-2) analysis to the definition of specific behavioral objectives or training tasks and the training media upon which these objectives may most economically and beneficially be achieved. These media range from mockups and carrels to advanced simulators and the weapons system itself. Adequacy and efficiency of the training devices are judged on their capacity to effectively implant in the student the proper reaction to the sum total of sensory cues presented. Subjective as this transferability is, experience has indicated that learning transfer is a direct function of the fidelity of the specific device with regard to the sensory cues presented in the aircraft.

The tactical/mission qualification phase is aimed at certifying the student in the mission of the unit to which he is assigned. Specific operational skills were acquired in CCT. Application of these skills to the unit mission is the goal of the third phase. Unlike the first two phases, there is only limited commonality in the specific desired outcomes of this phase. Furthermore, the tasks are changed as the mission is changed. Because of these variances in training tasks or objectives across the specific weapon system and with time, the training syllabi must be dynamic and quickly adaptable to the unit mission. The training media, therefore, require considerable flexibility in order to adapt to these changes.

The continuation phase consists of skill maintenance activity on a recurring basis. The purpose of this training is to provide the optimum frequency of exposure to specific behavioral objectives to ensure flying skills are retained.

2. Established Training Programs

At present, SAC conducts Combat Crew Training for aircrews of the following aircraft: B52D/G/H; KC-135; RC/EC-135; FB-111; U-2 and SR-71.

SAC's DC-130 pilots receive CCT through Tactical Air Command (C-130E) and Air Force Reserve (C-130A). The tactical/mission qualification phase of training is accomplished by SAC for the crews of all the above mentioned aircraft, including the DC-130.

3. ISD Activities

SAC has historically utilized concepts similar to ISD in developing and updating its training programs. Current efforts include contracts for rigorous ISD analysis of the B-52 and KC-135 training syllabi. The outcome of these contracts shall be training syllabi for each aircraft and defined and quantified training equipment requirements. The B-1 ISD has begun within the B-1 SPO. The result will also be a training syllabus and definition of training equipment. Although the equipment required for all programs will most likely be a combination of egress trainers, audio-visual training stations, part-task trainers, procedures trainers and simulators, only the simulator and more sophisticated crew station trainer requirements are addressed here. The other training media are an order of magnitude less expensive and are designed as logical training media progressions leading to the simulator. In addition, past experience allows the users to more firmly estimate the number of simulators required. The uncertainty attached to the utilization of the less sophisticated devices and their relatively minor cost directs deferment of their further considerations in this Plan.

In an effort to quantify B-52 and KC-135 skill maintenance needs, rigorous tests are conducted using various training media and cross sections of qualified aircrews. An example of this type of analysis is contained in the GIANT SAMPLE test program. A fundamental objective of this test is to see if aircrews at the selected test units can maintain a desired level of proficiency with a significantly reduced monthly flying hour allocation. An attempt will be made to compensate for the reduced flying time by a correspondingly significant increase in the use of simulation devices. On the remaining flying sorties, an attempt has been made to streamline the sortie profile so that much "dead head" or unproductive flying time has been reduced or eliminated. SAC will collect and analyze raw data on crew proficiency levels by individual crew position. The comparison between test and standard units will also be based upon the number of hours flown and the frequency of event accomplishment. The test is scheduled to continue for an 18 month period, but the time may be extended if additional long range data is needed. Preliminary SAC and AFHRL conclusion associated with this test is the inability to accurately assess performance degradation without a measurement capability in the present generation training equipment. These deficiencies will be corrected in the advanced B-52/KC-135 mission simulators.

B. TRAINING DEVICE STATUS AND REQUIREMENTS

1. B-52

The B-52D, G and H aircraft are projected to have a service life extending at a minimum into the mid to late 1980s and most likely into the 1990s. The training devices in use are analog units procured during the 1950s. Static trainers are utilized at the CCTS while static or rail mounted units serve the operational wings. These devices are being utilized to the maximum extent possible considering time down for maintenance and travel (for rail mounted trainers). Continued utilization is hampered by the increasing difficulty being experienced in procuring spare parts since the vendors, at least those who still exist, have long ago ceased production of similar units.

Exact number of existing trainers for the aircraft are outlined in Table VIII-1.

a. Flight Trainer

The existent flight trainers are actually cockpit procedures trainers. No limited motion system is provided. Performance characteristics are based upon empirical data. No visual system is incorporated, nor is there any electrooptical capability.

In order to provide more training or increased flying time reductions, new simulators are required. SAC-ROC 7-73 has been validated for a limited air-to-air refueling part task trainer in order to meet this training requirement.

The training devices needed for adequate training in conjunction with reduced flying are digitally controlled simulators which incorporate the following: a six degree of freedom (DOF) motion base; a 140° x 30° visual system takeoff, landing, and air-to-air refueling; and a coordinated presentation of the radar, low light level television (LLLTV) and forward looking infrared (FLIR) systems (SAC ROC 8-74).

TABLE VIII-1

CURRENT TRAINERS

TYPE		NUMBER @ COMBAT CREW TRAINING STATIONS	NUMBER @ OPERATIONAL UNITS	TOTAL COST / YEAR ($ K)
B-52D				
P/CP	S	1	4	263
N/B	PTT	2	4	263
EWO	PTT	1	4	306
FCSO	PTT	1	4	103
				935
B-52G				
P/CP	S	2	4	762
	PTT	2	0	144
N/B	PTT	2	10	937
EWO	PTT	3	10	854
FCSO	PTT	2	10	304
				3,001
B-52H				
P/CP	S	1	2	418
	PTT	1	0	43
N/B	PTT	1	6	503
EWO	PTT	1	6	453
FCSO	PTT	1	6	179
				1,596
KC/RC/EC-135				
P/CP	S	4	15	2,367
	PTT	1	0	251
NAV	PTT	1	0	170
BOOM OP.	PTT	0	0	00
				2,788
FB-111				
PILOT/NAV	MS	1	2	926
NAV	PTT	1	0	UNK
SRAM	PTT	1	0	UNK
EGRESS	PTT	1	0	15
				941+
U-2 @				
PILOT	S	2	N/A	79
SR-71 @				
PILOT	MS	1	N/A	43
NAV	MS	1	N/A	40
				83

LEGEND: S - SIMULATOR; MS - MISSION SIMULATOR; PTT - PART TASK TRAINER; P/CP - PILOT/COPILOT; N/B - NAVIGATOR/BOMBARDIER; EWO - ELECTRONIC WARFARE OFFICER; FCSO - GUNNER.

@ - CCTS AND OPERATIONAL UNIT COLOCATED.

b. Offensive Systems Trainer

The Offensive Systems Trainers in use are devices built for the B-36 and subsequently modified for the B-47 and B-52. The trainer provides adequate training in the medium and high level radar profile but is severely limited as a training tool for low level missions. Breakout of targets at short range is physically impossible with the equipment presently being utilized. Interface between the SRAM inertial measurement unit and the trainer has also proven inadequate. There are no capabilities for FLIR or LLLTV simulation.

The device needed for improving the quality of training for B-52 Offensive Systems Operators is outlined in SAC ROC 8-74. Trainer capabilities required include Digital Radar Landmass Simulation (DRLMS), FLIR, SRAM and LLLTV simulation. DRLMS, FLIR and LLLTV capabilities require R&D effort. In addition, the new Offensive Systems Trainer will have to be capable of providing training in conjunction with the Flight Simulator and Defensive Systems Trainer or in an independent mode. This flexibility will provide the additional capability of integrated crew training which is today only available in the aircraft.

c. Defensive Systems Trainer

The Electronic Warfare Trainer in use today for B-52 aircrews is an analog device which provides fairly realistic simulation of electronic warfare operation aboard the aircraft. The system is capable of presenting 54 hostile electronic emitters. Aircraft countermeasures operation is simulated with high fidelity.

The shortcomings of this trainer are: its age and associated supply difficulties; its analog nature; its limited threat display capability; its lack of interface with other crew stations; and the requirement for tapes of actual electronic emitters for updating of the trainer's programmed threat display.

A single gunnery trainer is available at each wing and at the CCT Squadron. Training is limited to the presentation of ten preprogrammed targets. Programming flexibility is very limited. No interface with the Electronic Warfare Officer or other crew/stations is provided.

The Defensive System Trainer required by SAC must incorporate digital computation in order to expand the threat presentation and provide flexibility for update and modification of the threats and equipment. The trainer should more nearly duplicate the actual aircrew functional environment by combining the electronic Warfare Officer and Fire Control System stations. Aerial threats could thus be handed-off to the gunner. Furthermore, the threat should be varied with each student mission. Interface with the landmass data base would provide terrain occult to more accurately duplicate the actual low-level mission.

2. KC-135

The KC-135 aircrew trainers are of 1950 vintage and facing the same supply difficulties as the B-52 trainers. Number and disposition of the present system are outlined in Table VIII-1. The trainers are being fully utilized in their present configuration. USAF ROC 6-74 provides for a low cost visual modification to provide training in the critical engine-out on takeoff maneuver. This capability will additionally be used to support in-unit pilot upgrades.

a. Flight Trainer

The KC-135 Flight Trainers are cockpit procedures trainers affording adequate instruction in normal and emergency procedures. Lack of a visual or motion system restricts any training associated with flying characteristics.

SAC's requirements in support of a decreased flying program, are for an up-to-date flight simulator with a six DOF motion system and a limited visual system for takeoff, approach, landing and runway operations. The visual system must be a high fidelity day/night system for the CCTS simulators. The operational units will not require as capable a device and will probably need a night only system. Detailed requirements are reflected in SAC ROC 10-74.

b. Navigation Trainer

The existing navigation trainer provides initial orientation to KC-135 CCT navigators in the aircraft's radar operation. SAC's stated requirement is for an aircraft-identical station with high fidelity radar simulation. A DRLMS-type system and real time celestial information for simulation of the navigation function are desired. Interface with the Flight Simulator is required.

c. Boom Operator Trainer

At present the aircraft is the only device available to train boom operators. SAC ROC 2-74 identified the need for a trainer for CCT boom operators. The trainer should be identical to the aircraft crew station with a 48° x 30° FOV visual system presenting a landmass, the various receiver aircraft, and the boom. While the ROC currently specifies the requirement for a single engineering model to be used in CCTS, a favorable test program could result in a production decision for thirty-three units.

3. RC/EC-135

All ground training for RC/EC-135 aircrews is accomplished in KC-135 training devices. The flying portion of CCT is accomplished on the KC-135 aircraft. Initial introduction of the RC/EC aircraft systems is accomplished in a "difference course" accomplished at the operational unit.

a. Flight Simulator

All requirements for the KC-135 Flight Simulator apply to this system. The EC/RC-135 simulator would be a version of the KC-135 simulator modified for EC-135 cockpit configuration and flight and engine characteristics. Pilot difference training from EC to RC will not be extensive. No program direction has been received to produce a separate RC-135 flight station or simulate RC-135 performance characteristics.

b. Navigation Trainer

Two navigation stations (one EC configured and one RC configured) would be provided with the EC/RC-135 simulator to permit realistic training for two different navigation roles.

c. Aerial Refueling Trainer

A part task aerial refueling trainer will satisfy the EC/RC-135 receiver requirement under SAC ROC 7-73.

d. EW Mission Trainer

The RC-135, in pursuit of its electronic intelligence (ELINT) gathering mission, includes three Electronic

Warfare Officers in its crew. No device is available today for either initial or recurring training of these crew members in the operation of the equipment on board the aircraft. Normal aircraft training flights cannot provide the training required for proficient mission performance. SAC ROC 9-74 states this need.

4. FB-111

The FB-111 simulators are among the best operational training devices in use today. Flight controls, instrument indications, navigation, bombing and motion systems are accurately integrated to realistically portray actual flight.

The radar system in the simulator falls short of the other systems in its training value. The quality and fidelity of the presentation is not comparable to that of the aircraft's radar. In addition, there is inadequate correlation between the presentation on the terrain following radar and the attack radar. Implementation of improved simulated radar technology would improve the training value of the simulator and further reduce flying training requirements. SAC, pursuant to the production goals of TAC ROC 21-71 (ASD Project 1183, DRLMS), expects to digitize the landmass and various radar subsystems in order to realize these advantages.

Optimization of the present system may also be approached through incorporation of a visual system. SAC ROC 13-72 identified the requirement for such a system for takeoff, landing and ground operations. This ROC is likely to be amended to include an AAR capability.

These modifications are required to upgrade the quality of the training. Actual flying time reductions are not the primary driving force in this submission. However, reduced flying requirements are expected to be a direct fallout of implementation of these modifications. Due to the present FB-111A mission simulator workload, further flying reductions will be difficult without added training equipment.

5. U-2 Training Program

There are highly experienced pilots flying the U-2. Two models of the aircraft, each with markedly different cockpit configurations and handling characteristics, are being utilized. The pilots fly one or the other models, but not both.

Instrument training is performed in T-40 and C-11 instrument trainers. The T-40 is modified to give U-2 performance indications. Recurring flying training requirements are four landings per month for pilots with less than 300 hours in the aircraft and three landings per month for those pilots with more than 300 hours.

Because of the limited number of pilots in the program and their high experience and capability levels, no other training devices are required.

6. SR-71 Training Program

The SR-71 training program is similar to the U-2 in the limited number of crews flying the aircraft (10), and the experience and capability levels of those crews. However, SAC has an integrated/stand alone mission simulator for the aircraft and it is being utilized for initial training of new crew members. In addition, the simulator is used as a medium for pre-flying each mission flown from the CCTS base, whether that mission is for initial training or for operational purposes.

The utilization rate of the simulator and number and expertise of the crews makes any modification or addition to the simulator less than economically desirable.

7. B-1

The quantity, fidelity and configuration requirements of B-1 training devices are dependent upon the outcome of the ISD analysis presently being performed and expected to be completed in July 1975. The very nature of this aircraft indicates an expected requirement for a high fidelity device, especially in the avionics and electro-optical subsystems. Because of the extensive R&D that must be accomplished prior to deployment of operable simulation systems, the cost estimates for the B-1 training devices must not be used as firm programming objectives. The figures are simply gross estimates.

a. Avionics Trainers

SAC anticipates a requirement for two avionics trainers which will familiarize the Offensive and Defensive Systems Operators with all the procedures and operating characteristics of the avionics aboard the B-1. These devices will be utilized only at the CCTS and are intended as the training medium upon which these crew members will acquire the operational skills requisite for integrated mission training in the simulator.

b. Flight Simulator

The flight simulator is seen as a device for training the entire four man crew. DRLMS, FLIR and LLLTV must be incorporated as in the avionics trainer. The pilots will also need a limited visual system for takeoff, landing and air-to-air refueling. The capability for individual or integrated training for any or all crew stations will maximize the training potential of the system.

C. PROGRAM DATA

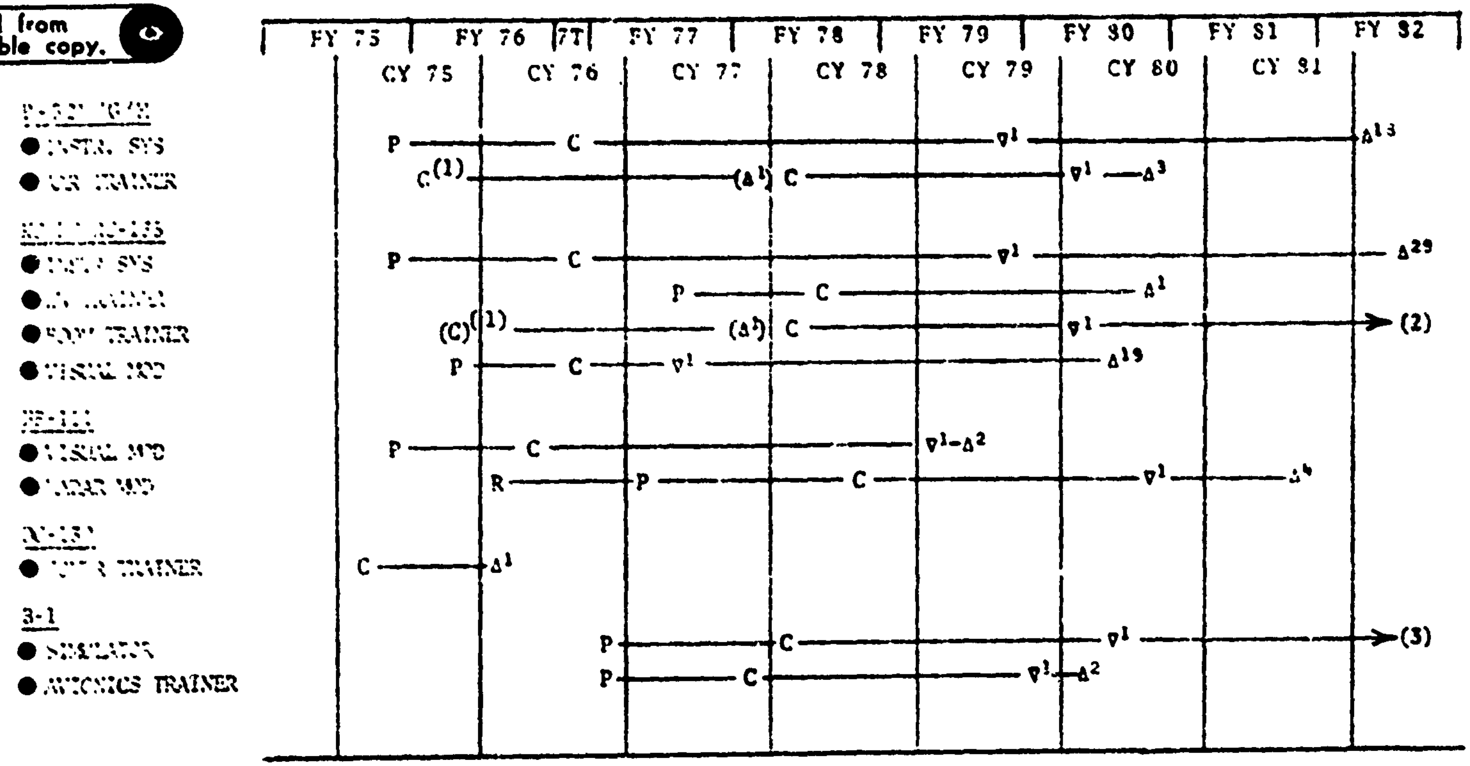
Program schedules are illustrated in Figure VIII-1. Deployment of the simulators is listed in Table VIII-2.

Several significant assumptions were made in estimating quantities of equipments. These were:

1. Projected simulator to flying time ratios were set at 2.0 and 1.6 for the CCTS and in-unit training, respectively. However, there has been no proven ratio for simulator transferability and SAC chose to adopt a more conservative approach than did OMB in its realization of training benefits from simulators.

2. The RC and EC-135 Flight Simulators are seen as modifications to the KC-135 Simulator. Delivery of these and the two associated Navigation and Boom Operator Trainers is assumed to be made in FY 80.

3. In general, the cost estimates reflect high levels of sophistication. Whether or not the sophistication is warranted depends upon the training value of the device. Until trade offs between the cost of each training capability and the value of that capability are made, the economic justification will be impossible. These trades cannot be assessed until ISD data can be collected and analyzed using actual samplings of student crews and the operational simulator hardware. The feasibility of the B-52 G and H Offensive Systems Trainer and B-1 training devices is especially tenuous since the electrooptical simulation R&D they will require has not been started.



LEGEND: R = ROC ISSUED
P = PMD
C = CONTRACT AWARD
∇ = 1ST DELIVERY
Δ = LAST DELIVERY

(1) PROTOTYPE
(2) Δ^{33} 3RD QUARTER FY 83
(3) Δ^{16} 3RD QUARTER FY 83

FIGURE VIII-1. SAC PLANNING SCHEDULE

TABLE VIII-2

REQUIRED SIMULATION DEVICES

	COMBAT CREW TRAINING STATION	RECURRING
B-52D		
AAR TRAINER	1	
B-52G		
PILOT/COPILOT	2	10
OFFENSIVE SYSTEM	4	10
DEFENSIVE SYSTEM	2	10
AAR TRAINER	1	
B-52H		
PILOT/COPILOT	1	5
OFFENSIVE SYSTEM	3	5
DEFENSIVE SYSTEM	1	5
AAR TRAINER	1	
KC-135		
FLIGHT SIMULATOR	3	25
BOOM OPERATOR	5	25
NAV TRAINER	3	25
RC-135		
PILOT/COPILOT		1
ELINT TRAINER		1
NAV TRAINER		1
BOOM TRAINER		1
AAR TRAINER		1
EC-135		
NAV TRAINER		1
BOOM TRAINER		1
FB-111		
PILOT/NAV-VISUAL	1	2
RADAR MOD	2	2
DC-130		
CONTROLLERS	1/2	
B-1		
FLIGHT SIMULATOR	4	12
AVIONICS TRAINER	2	

4. Except for the B-52 AAR and KC-135 Boom Operator Trainer, all schedules assume that production contracts are let at the beginning of the program. This is a high risk schedule in that there is considerable uncertainty associated with every new simulator, especially in the visual systems that many of these devices incorporate. There will normally be a year to two delay between delivery of the prototype and the first production article. With respect to the entire program, however, this assumption is partially offset by the conservative production rates attached to each program.

D. IMPACT OF NEW CAPABILITIES ON TRAINING PROGRAMS

Training Hours

In developing the equipment requirement as set forth in this Plan, SAC has adopted as an objective, the reductions of flying time as set forth in the OMB study of 26 July 1973. This translates into a 50% reduction in CCT flying and a 20% reduction in continuation flying training accomplished at the operational units. While the command feels that the fifty percent CCTS flying reduction is optimistic, it is confident that an overall 25% reduction to a zero simulator baseline can be demonstrated by 1981. Further, they believe that the crews will be better trained by increasing their exposure to the realms of the mission which today are restricted because of ecological or safety considerations.

Current and projected flying hour programs are given in Table VIII-3 for aircraft affected by this Plan. The B-1 flying hours are not defined at this time although simulator utilization is forecast at 12 hours/month/crew for combat-ready crews and 64 hours/crew during CCT.

E. COMMAND PRIORITIZATION OF NEW CAPABILITIES

SAC's prioritization of new training systems is based on maximizing investment returns of weapon system packages at the earliest date. The order of priority for trainers identified is:

1. B-52 CCTS devices and supporting R&D efforts.

2. B-1 CCTS devices and supporting R&D.

TABLE VIII-3

SAC TRAINING PROGRAM SUMMARY

	CURRENT				PROJECTED			
	TRANSITION		CONTINUATION		TRANSITION		CONTINUATION	
	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME
B-52D								
PILOT/COPILOT	39	141.1	24	260	SAME	SAME	SAME	SAME
OFFENSIVE SYSTEM	18	141.1	36	260				
DEFENSIVE SYSTEM	32/37*	141.1	35/48*	260				
B-52G								
PILOT/COPILOT	39	154.7	24	260	195	73.5	123	208
OFFENSIVE SYSTEM	18	154.7	46	260	165.2	73.5	145	208
DEFENSIVE SYSTEM	32/37*	154.7	34/48*	260	165.2	73.5	133	208
B-52H								
PILOT/COPILOT	39	156.4	24	260	195	73.5	123	208
OFFENSIVE SYSTEM	18	156.4	46	260	165.2	73.5	145	208
DEFENSIVE SYSTEM	32/37*	156.4	33/48*	260	165.2	73.5	133	208
KC/EC/RC-135								
PILOT/COPILOT	27	66	24	248.4	100	33.5	104	198.4
NAVIGATOR	3	66	0	248.4	67	33.5	80	198.4
BOOM OPERATOR	0	78	0	248.4	67	33.5	80	198.4
FB-111								
PILOT	76.5	61	62	150	SAME	SAME	SAME	SAME
NAVIGATOR	96.[illegible]	29	62	150	SAME	SAME	SAME	SAME

* EWO/GUNNER

3. KC-135 CCTS devices.

4. B-52 unit equippage.

5. B-1 unit equippage.

6. KC-135 unit equippage.

SAC has broken out the priorities attached to individual training devices within the weapon systems according to the criticality of training task, availability of ground-based trainers, and estimated payback period as follows:

1. 32 Boom Operator Trainers (SAC ROC 2-74).

2. 3 B-52 Aerial Refueling Trainers (SAC ROC 7-73).

3. 18 B-52G/H Mission Simulators (SAC ROC 8-74). (Includes Flight Simulators, Offensive Simulators and Defensive Simulators).

4. 16 B-1 Mission Simulators.

5. 29 KC-135 Mission Simulators (SAC ROC 10-74). (Mission Simulator includes Flight Simulator and Nav Trainer).

6. 2 B-1 Avionics Trainers.

7. 4 B-52G/H Offensive Trainers (SAC ROC 8-74).

8. 1 EC/RC-135 Mission Simulator (SAC ROC 10-74).

9. RC-135 EW Trainer (ELINT) (SAC ROC 9-74).

The following ROCs have been validated and identified for FY 74 or FY 75 funding:

ROC NUMBER	DESCRIPTION
USAF ROC 11-7	Conversion of two B-52 Flight Trainers
SAC ROC 13-72	Visual System for FB-111 Mission Simulators
SAC ROC 5-73	Drone Flight Simulator
SAC ROC 7-73	B-52 AAR Trainer
SAC ROC 8-74	B-52 Instructional System
SAC ROC 10-74	KC-135 Instructional System

With the exception of FLIR and LLLTV simulation (and DRLMS to a lesser extent), SAC's requirements are all within the state-of-the-art.

F. ADVANCED SYSTEMS - R&D IMPLICATIONS

The B-52 and B-1 will have incorporated electrooptical technology for which there is no adequate simulation today. Planned mission profiles indicate heavy reliance upon the E/O systems. Therefore, proficiency in the interpretation and utilization of these systems is a primary training objective.

R&D must be accomplished before the FLIR and LLLTV associated tasks can be effectively introduced into ground-based training systems. Until this capability is acquired, B-52 flying time reductions will be limited. In the interim, the training will have to be accomplished in the aircraft. Airframe structural deterioration, excessive fuel utilization and possible ecological disturbances will be encountered while these E/O simulation capabilities are being researched and developed. The B-1 is expected to encounter these same difficulties.

SECTION IX

AEROSPACE DEFENSE COMMAND (ADC)

A. GENERAL

The Aerospace Defense Command conducts conversion and operational training for the F-101, F-106, EB-57, EC-121 and T-33 aircraft. The one F-4C squadron assigned to ADC is provided conversion training by the Tactical Air Command (TAC) with ADC providing required operational training. Beginning in May 1975, training of aircrews for T-37 aircraft, in support of AFA Cadet Orientation Programs, was initiated at Peterson Field, Colorado. The C-118, C-131, T-29 and T-39 training was terminated in May 1975 in conjunction with the revised program for administrative airlift. Although ADC has responsibility for defining training requirements for the F-101 and F-102 weapon systems, both conversion and operational training are provided by the Air National Guard (ANG). Worldwide Air Defense Enhancement (WWADE) training is conducted at the Air Defense Weapons Center for USAF pilots assigned to the Air Defense mission. However, with its current simulator capability, ADC does not consider that the OMB FY-80 goals can be achieved without significant degradation of mission capability. ADC considers it essential that Air Force recognizes the difference among various Air Force weapons systems in determining the feasibility of moving training events from the aircraft to the simulator, and does not attempt to support arbitrary goals applied uniformly to all weapons systems.

There are two aspects of flying hour reductions that are possibly unique to ADC. One is the interrelation of aircraft and ground environment in a complete air defense system. It will be essential to develop linked aircrew/controller simulation facilities to replace the live intercept controller training that will be lost if interceptor flying is reduced, and to avoid degradation of an essential part of the system. The second important aspect is the absolutely vital need to have available an adequate target force for operational training, including exercises for the entire air defense system. These targets are at present provided mainly by EB-57 and T-33A forces, which while providing this function also provide more than sufficient training for their crews. The former rather than the latter drives the flying hour requirement, and considerably negates the need for substantially increased simulation in these mission support aircraft.

Another important aspect of increased reliance on simulation is effective management of training systems. Although this subject is not one of the directed objectives of the study, it was addressed in the Scientific Advisory Board Report and ADC considers that it is of sufficient importance to be addressed. If in the future it is necessary to rely so heavily on simulation, if proper return is to be obtained from the investment involved, and if simulators are to remain in step with the aircraft configuration, it will be essential to manage simulators (and supporting training media) in a considerably more effective manner than hitherto. ADC views are, that this can only be achieved if simulation equipment is an integrated part of the entire weapon system and is managed, maintained, and supported in similar fashion to aircraft resources. ADC includes in this view an essential need to provide adequate manufacturer's technical representation at least for the first year after delivery of new systems.

ADC considers that the severe cuts proposed in UPT flying hours could have a very serious adverse affect on the level of proficiency of UPT graduates entering that Command. Its observations are that the effectiveness of synthetic training increases as flying experience increases. A sound background of flying experience is an essential bedrock upon which to base the increasing exposure to simulation that a pilot will meet during his career. Therefore, ADC has consistently opposed any reduction of UPT flying hours and has found for many years that the graduate's ability has had to be improved by lead-in training entry to its more demanding weapon systems. We need a higher standard of graduate, not a lower one, and we, therefore, support more simulation during UPT, but not at the expense of reduced flying.

ADC recognizes that it has only limited experience with regards to the potentialities of modern simulation. Table IX-1 presents the aforementioned weapon systems, the principal trainee(s), and the current status of ISD efforts.

As can be observed in Table IX-1, ISD studies are well underway within ADC and experience indicates that minimal reduction in aircraft training hours can be realized utilizing current analog simulators along with ISD-developed syllabi. The greatest impact of ISD on current flying training courses will probably be in maximizing quality,

TABLE IX-1

CURRENT TRAINING STATUS FOR ADC WEAPONS SYSTEMS

PRINCIPAL TRAINEE(S)	WEAPON SYSTEM	TYPE SCHOOL	SIMULATOR AVAILABLE	STATUS OF ISD EFFORT
PILOT	F-106	COMBAT CREW TRAINING	PART TASK TRAINER	COMPLETE - FEB 1974 IN IMPLEMENTATION PHASE
PILOT/WSO	EB-57	SQUADRON CHECKOUT	NO	INITIATED - FEB 1974 COMPLETION - JAN 1975
PILOT	T-33	QUALIFICATION COURSE	INSTRUMENT TRAINER	INITIATED - APR 1975 COMPLETION - MAR 1976
PILOT/ NAVIGATOR/ CONTROLLER	EC-121	COMBAT CREW TRAINING	YES	IN PROCESS COMPLETE - OCT 1974
PILOT/WSO	F-4C	COMBAT CREW TRAINING	USES TAC SIMULATOR	ACCOMPLISHED BY TAC SPINOFF TO ADC
PILOT/WSO	F-4D/E	WWADE	YES	INITIATED MAY 1975 AND CONTINUING
PILOT/WSO	F-101	COMBAT CREW TRAINING	YES	IN PLANNING STAGE
PILOT	F-102	COMBAT CREW TRAINING	YES	BETWEEN ADC AND ANG

validity, and efficiency. However, with a system for simultaneous pilot/controller training, substantial reduction in annual flying hours can be realized together with improved training capability.

B. TRAINING DEVICE STATUS AND REQUIREMENTS

In assessing its simulator requirements ADC concluded that only the F-106 and follow-on interceptor aircraft satisfy the ground rules established for projecting future simulator requirements. ADC considers that other aircraft within its inventory do not satisfy these ground rules because of the limited quantity, short remaining life, considerable training being accomplished via target support, and/or the low operating cost. Therefore, large investments for simulator devices and improvements in simulation facilities for these weapon systems are not justified.

1. Present Status

a. Limitations of the existing MB-42A simulator confine the primary benefits to procedural training in most normal aircraft operating procedures, approximately half of the aircraft emergency operating procedures, and half of the fire control system operations.

b. The MB-42A has no capability to simulate contact flying, such as visual takeoffs/landings, patterns, formation, air refueling and air combat maneuvering. In addition, severe limits exist in fire control system simulation for low altitude intercept training, tactical data link and target characteristic simulation.

c. Increased use of present equipment can provide only marginal offset to flying hour cuts due to the lack of additional training events transferable from the aircraft to the simulator.

d. On 5 February 1975, HQ USAF issued PMC No. R-Q5013-(6) stating that ROC 6-74 requirement for an advanced interceptor simulator (AIS) was consistent with force structure planning and was endorsed. It recommended that ADCOM prepare a ROC for appropriate simulation capabilities upon identification of the future interceptor force. Since the follow-on interceptor (FOI) has not been identified, a ROC has not been submitted. However, ADC is accumulating information based on training requirements and known capabilities of potential FOI candidates. The basic requirement, as previously stated, for an AIS is still valid.

e. Since the PMD did not provide further guidance, the ADC initiated concerted action to identify and describe a series of upgrade modifications for existing MB-42 simulators. With support of Ogden ALC and AFLC/MM, the 23 modifications at Tyndall AFB, Florida, have been prototyped. The AFLC Form 48 was certified by this Command on 17 July 1975. Kits will be requested in September with kit delivery programmed for November. All kits will be delivered and installed by February 1976 (1 November, 3 December, 4 January, 4 February, 2 March). Although the modifications provide significant improvement in the simulator (more compatible with the aircraft), there will not be a significant replacement of flying sorties. However, training now can more readily be transferred to the aircraft with a better degree of reliability.

Upon identification of the future interceptor force, ADC will restate the ROC requirement tempered with technological growth, AFHRL studies and guidance of the Simulator Advisory Group.

2. Advanced Interceptor Simulator (AIS)

a. The concept of a new advanced interceptor simulator is for full mission capability. It includes:

(1) A six degrees of freedom motion base,

(2) Visual capability of approximately 2/3 spherical coverage similar to that currently under development for the Tactical Air Combat Simulator (TACS),

(3) Modularize component design to maximize transfer of simulator components to follow-on simulators,

(4) SAGE/BUIC tie-in with aircrew simulators for simultaneous pilot/controller training,

(5) Instructional features improvement; e.g., performance playback, sequence events, point reinitiation, automatic/manual malfunction insertion, replay for debriefing, etc., and

(6) A dual maneuvering simulator for Tyndall AFB. This simulator would consist of two cockpits, each having six DOF motion bases and two thirds spherical visual coverage. This simulator would have the capability to accomplish air combat maneuvering (ACM) through the use of the two cockpit stations and also the capability for each cockpit to operate autonomously against both preprogrammed targets and instructor (operator) controllable targets. Simulators for the remaining ADC/ANG units would consist of a single cockpit position with all of the above features except ACM through the use of dual cockpits. In addition, all simulators will have the SAGE/BUIC tie-in.

b. The above features would enable simulator accomplishment of all the major mission segments specified by ADC for the interceptor mission. While the basic flight simulator and motion base systems are considered state-of-the-art, an acceptable visual system for the AIS depends on the outcome of R&D in this area. An alternative to this visual system would be adaptation of the design used in the Advanced Simulator for Undergraduate Pilot Training.

C. PROGRAM DATA

The schedules for the AIS and the MB-42A modification programs are shown in Figure IX-1.

D. IMPACT OF NEW CAPABILITIES OF TRAINING PROGRAMS

The current and projected annual training hours are shown in Table IX-2 for the single crew member (pilot) if the AIS were applied to the F-106 training program. Also shown are the number of crews trained per year and the total simulator and flight hours devoted to transition (conversion) and continuation (operational) training. The data for the AIS includes an approximate 23% reduction in flying hours for conversion training and about 10% reduction for operations training. However, operational training is the dominant training program within ADC for the F-106; therefore, the overall percent reduction in

SUMMARY SCHEDULE

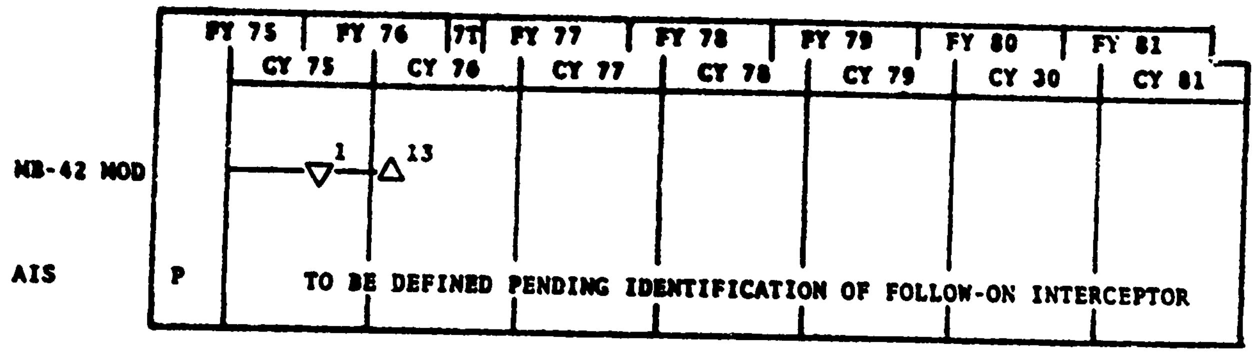


FIGURE IX-1. FUTURE ADC SIMULATORS

TABLE IX-2

AEROSPACE DEFENSE COMMAND TRAINING PROGRAM SUMMARY

	CURRENT				PROJECTED			
	TRANSITION		CONTINUATION		TRANSITION		CONTINUATION	
	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME	SIM TIME	FLT TIME
F-106 (AIS)								
PILOT	26	74.5	45	192	39	57.5	61	173
WSO								
TOTAL/CREW	26	74.5	45	192	39	57.5	61	173
#CREW/YR	76	76	217	217	76	76	217	217
TOTAL/YR (1000's hrs)	1.98	5.67	9.77	41.66	2.96	4.37	13.24	37.54

flying hours approximates 11.5%. Currently the total annual flying hour program for the F-106 includes 47,330 hours. The Advanced Interceptor Simulator (AIS) could reduce this figure to 41,910 hours for an annual reduction of 5,200 hours. Estimates for AIS application to the yet to be identified future interceptor are not available at this time.

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